

THE MANUFACTURE OF
LUBRICANTS
SHOE POLISHES
AND
LEATHER DRESSINGS

BY
RICHARD BRUNNER

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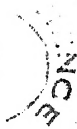
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PREFACE.

THE preparation of lubricating oils and greases, shoe polishes and leather softening materials are conveniently grouped together, since the materials employed in their preparation are essentially similar. In the compounding of these substances the old rule of thumb methods no longer apply, both scientific and technical knowledge being required in order that the materials may be fitted for particular purposes.

In the present volume the author has given a short account of the extraction and purification of the various animal and vegetable oils and fats, the chemical composition of oils and fats; the preparation of mineral oils, rosin oils, soaps, mineral matters, etc., which are employed in this industry. Numerous recipes are given for the preparation of lubricating oils and greases, blackings, leather varnishes and leather softening preparations. The lubrication of machinery and the various forms of lubricators are considered and also the methods of testing lubricating oils.

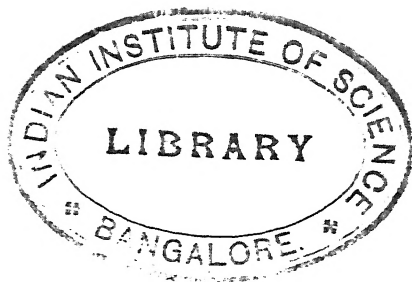
In the present edition much new matter has been introduced in connection with the composition of oils and fats, emulsion lubricants, the graphite preparations, "aquadag" and "oildag" of Dr. Acheson, the "Germ Theory" of lubrication of Messrs. Wells and Southcombe, etc., etc.

The cleaning of oily waste and the recovery of used lubricating oils—both essential to economical working—are considered together with the removal of thickened grease and oil.

In placing this edition before the public the reviser ventures to hope that manufacturers of lubricating oils, boot polishes, and leather dressings, will find within its covers much that is of interest and possibly of value relating to the industries in which they are engaged.

H. B. STOCKS.

LONDON, *December*, 1922.



CONTENTS.

PART I.

CHAP.	PAGES
I. INTRODUCTORY. PROPERTIES OF LUBRICANTS.—Irregularities on metal surfaces; types of lubricants . . .	1-7
II. SUBSTANCES USED IN THE PREPARATION OF LUBRICANTS.— Animal oils and fats; vegetable oils and fats; treated oils; hydrocarbon oils, etc.; soaps; mineral substances; composition of fats and oils; triglycerides; fatty acids; alcohols; preparation of fats and oils; refining oils for lubricating purposes; properties of fats and oils; treated oils	8-52
III. SUBSTANCES USED IN THE PREPARATION OF LUBRICANTS (continued).—Hydrocarbon oils, etc.; petroleum oils; coal-tar oils; shale oils; lignite oils; rosin; rosin oils; paraffin; asphaltum; indiarubber; guttapercha	52-84
IV. SUBSTANCES USED IN THE PREPARATION OF LUBRICANTS (continued).—Soaps; soda soaps; potash soaps; lime soaps; magnesia soaps; mineral substances; graphite or black lead; artificial graphite; steatite or talc; soapstone; mica; sulphur; soda; lime; litharge; lead acetate; ammonia	85-96
V. SOLID LUBRICANTS.—Tallow lubricants; train oil greases; bone fat greases; sulphur axle grease; Booth's patent greases; tallow and neatsfoot oil greases; palm oil greases	97-110
VI. LEAD SOAP LUBRICANTS.—Lead oleate axle grease	111-113
VII. TRUE SOAP GREASES. Charlton's soap grease; tallow, oil and soap grease; carriage axle grease	114-115

CHAP.	PAGE
VIII. CAOUTCHOUC LUBRICANTS.—Doulon's caoutchouc grease; caoutchouc machine grease; American caoutchouc grease; caoutchouc adhesion grease; caoutchouc and guttapercha grease; caoutchouc axle grease; caoutchouc and fat grease	116-118
IX. OTHER SOLID LUBRICANTS.—Asphaltum axle grease; naphthalene grease; rosin machine grease; graphite axle grease; graphite grease for quick-running axles; cart greases; palm oil waggon grease; waggon grease; wheel greases; solidified oils	119-124
X. LIQUID LUBRICANTS.—Lubricating oils in general; materials used	125-126
XI. COHESION OILS.	127-129
XII. LUBRICANTS COMPOSED OF FAT OR OIL AND ROSIN OIL.— Rosin oil and train oil lubricant; solar oil lubricant; thick oil lubricants; patent rosin oil axle grease; rosin greases; paraffin oil greases; paraffin and petroleum jelly grease	130-133
XIII. LUBRICANTS FOR SPECIAL PURPOSES.—Greases for quick- running axles; piston-rod grease; cog-wheel grease; driving-belt grease; belting grease; caoutchouc grease for driving belts; Belgian cart grease; English patent axle grease; soap and mineral oil lubricants; Cole's patent lubricating oil; American machine oils and solid greases; turbine oils; rope grease for wire ropeways; Schuckart's patent belting grease; Drechsler's patent graphite lubricating powder	134-138
XIV. MINERAL LUBRICATING OILS.—Vulcan oil; globe oil; thick mineral lubricating oils; "vaseline"; "para- vaseline"; soap and petroleum jelly greases; lanolin lubricant; lanolin axle greases	139-141
XV. CYLINDER OILS.—Heavy mineral lubricating oils	142-145
XVI. THE "GERM PROCESS" OF LUBRICATION OF MESSRS. WELLS AND SOUTHCOMBE	146-148
XVII. CLOCKMAKERS' AND SEWING MACHINE OILS.—Fatty oils for clocks; olive oil for clockmakers' use; bone oil for clockmakers' use; fine machine oil; mineral oil for	

CONTENTS.

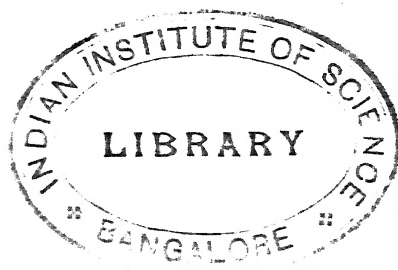
vii

CHAP.	PAGE
clockmakers' use; caoutchouc lubricant for sewing machines; mineral oil for sewing machines; sewing machine and clockmakers' oil; recipes for motor cylinder oils	149-154
XXVIII. EMULSION LUBRICANTS.—Soluble oils; sulphonated oils; Turkey red oils; soluble oils for machine tools; soluble mineral oils with an olein basis; soluble oils with a sulpholeate base; cutting oils; soluble oils and soluble compounds; analysis of sulphonated oils . . .	155-176
XIX. SUBSTITUTES FOR LUBRICATING OILS	177
XX. THE APPLICATION OF LUBRICANTS TO MACHINERY.—The flexible oil can; the aerostatic oil can; the oil cup; "Kirkham" patent snap drop oiler; "Kirkham" patent lubricator; Trier Bros.' patent automatic lubricator; The Diamond Lubricating Co.'s lubricators . . .	178-188
XXI. TESTING LUBRICATING OILS.—Bailey's Thurston's patent oil tester; Bailey's Boulton's patent cylinder lubricant tester	189-192
XXII. REMOVING THICKENED OIL AND GREASE	193-194
XXIII. CLEANING OIL RAGS AND COTTON WASTE.—Storing greasy rags or cotton waste; purifying waste lubricants; Hetmann's oil filter; Turner's patent oil filter . . .	195-198
XXIV. THE USE OF LUBRICANTS	199-200

PART II.

XXV. THE MANUFACTURE OF SHOE POLISHES AND PREPARATIONS FOR VARNISHING AND SOFTENING LEATHER . . .	201-202
XXVI. THE PREPARATION OF BONE BLACK.—Ivory black; the preparation of Frankfort black	203-205
XXVII. BLACKING AND SHOE POLISHES.—Glycerin; Vienna oil blacking; black polish in sticks; Lyons blacking; Hanoverian blacking; Berlin blacking; glue blacking; waterproof caoutchouc blacking; wax shoe polish; wax	

CHAP	PAGE
polish; spermaceti polish; guttapercha polish; patent leather staining preparation; lignite blacking; Belgian blacking; indigo blacking; glycerin blacking; liquid blacking; Lowy's blacking; iron blacking; ferrocyanide blacking	206-214
XXVIII. LEATHER VARNISHES.—Glossy varnishes; glossy black leather varnish; antacid boot-leather varnish; black leather varnish; harness varnish; black harness varnish; black varnish for belts; elastic leather varnish; caoutchouc varnishes; asphaltum varnishes	215-219
XXIX. LEATHER SOFTENING PREPARATIONS.—Soft grease for boot uppers; harness grease; glossy waterproof grease; waterproof leather greases; gloss for greased leather; fish oil leather grease; grease for wading boots; caoutchouc greases; petroleum jelly greases	220-225
XXX. THE MANUFACTURE OF DÉGRAS.—Production of dégras as a by-product in making shamoy leather; production of dégras from fish oil; olein dégras; black dégras; dégras from waste fat	226-229
INDEX	230-244





THE MANUFACTURE OF LUBRICANTS, SHOE POLISHES AND LEATHER DRESSINGS.

PART I.

THE MANUFACTURE OF LUBRICANTS AND GREASES.

CHAPTER I.

INTRODUCTORY.

THE progressive extension of machinery has caused attention to be drawn to the manufacture of substances facilitating the uniform and easy running of machines. Whereas formerly the only application of substances of this nature was to cart axles and simple machines, they have now to be used on all the countless auxiliary tools that human ingenuity has devised. When it is considered that one has to deal in this connection with movements ranging from the rotation of a ten-ton fly-wheel on its shaft to that of the smallest wheel in a watch, or that of a dynamo shaft running at over 1000 revolutions a minute, it becomes evident that the lubricants used for these purposes must be of a highly divergent character in order that they may be fitted for the work required, and also that the preparation of a lubricant suitable for a particular purpose is a task involving a considerable amount of consideration. The details given in the present work clearly show the large number of most diversified compositions which must be used in order to produce lubricants which will really be suitable for every purpose.

The name lubricant or grease is a generic term applied to

the substances used on machines and machine parts in places that are in mutual sliding or rolling contact.

In some cases the term grease is also used in connection with substances employed to soften leather, so that a distinction may be drawn between two groups of greases, namely, machine greases and leather greases.

The object of using any grease—whether intended for application to the parts of a watch, the axle of a farmer's waggon, or a Russia leather shoe—is always with a view to overcome, as far as possible, the friction or resistances opposing movement, and in addition, in the case of leather, to render the material supple and prevent it becoming hard.

These two purposes of greasing being so different, it will be necessary to consider them separately and we shall first devote our attention to the lubricants used for machinery.

The resistances opposing themselves to movement are usually termed frictional resistance. In many machines, especially those of a complex or heavy type, the frictional resistance is so great that a large expenditure of force is necessary to overcome it: and the heat generated by the friction is sufficient to make the parts in contact red hot, an instance of this conversion of friction into heat being afforded by the well-known "heating" of ungreased axles; it is only by the aid of suitable lubricants that frictional resistance can be reduced to such an extent that the loss of power in overcoming friction becomes comparatively small.

Many machines and machine parts are run at very high speeds, and it would be impossible to keep them running safely without the use of suitable lubricants. It is only necessary to mention as an example the extreme velocity with which the journals of railway carriages run in their bearings. If the two are turned ever so true and fitted carefully together, the frictional resistance would soon cause them both to become red hot. The same applies to the shafts of ventilating fans, electrical dynamos, and centrifugal separators. It is manifest that, in the absence of some lubricant, the parts in mutual sliding or rolling contact would be exposed to very considerable wear, since they would act on each other like two grindstones rubbing together.

It is therefore evident that the utility of lubricants is two-fold: in the first place, the use of a suitable lubricant reduces the frictional resistance to such an extent that it can be overcome without any undue expenditure of energy; and secondly, the parts in contact are protected against too rapid wear.

Before entering upon the subject of the various kinds of lubricants, it will perhaps be advisable to consider the question: In what does the efficacy of lubricants consist? This problem can be easily solved by a closer examination of the condition of the surfaces that are in mutual sliding or rolling friction.

If we examine with a powerful magnifying glass any hard and carefully polished body, even a steel plate polished until it reflects like a mirror, it will be found full of scratches and irregularities which have been produced by the polishing agent on its surface. In reality, therefore, even the most carefully polished body is by no means what it seems to be—namely, a perfectly smooth surface—but, on the contrary, is covered with irregularities, prominences and depressions, furrows and elongated scratches.

If we imagine to ourselves two such bodies sliding or rolling over one another without the application of a lubricant, we shall find that the prominences on the one catch in the depressions in the other, and *vice versâ*, with the result that a very considerable expenditure of power will be needed to lift the prominences on the one body out of the depressions in the other, or to draw them up as it were along an inclined plane. The frictional resistance, also, will be much greater, owing to the largely increased surface resulting from the inequalities.

With this high frictional resistance is associated still another phenomenon: when the speed is increased, the prominences on the one body will not always be lifted uniformly out of the depressions in the other, but many of them will be rubbed off, resulting on the one hand in a great expenditure of power, and on the other in a disproportionately rapid wear and tear of the parts in contact.

It will be easily understood that the frictional resistance

and wear will be greater in machine parts that are constructed of similar materials than in those of dissimilar materials, *e.g.* of two different metals or metal compositions, since similar surfaces will exhibit similar prominences and depressions, fitting into one another and only separable with difficulty.

On this account it is the practice in many instances to make machine parts, intended to slide or roll on one another, of dissimilar materials. Thus, for example, it is usual to make shafts of cast iron or steel, whilst the bearings in which they run are of bronze or other hard metal composition (bearing metal), these dissimilar metals wearing away less rapidly than similar ones.

With few exceptions, the lubricants introduced between machine parts in order to diminish their friction are either perfectly fluid substances or semi-solid bodies of the consistency of butter, these latter becoming fluid under the influence of the heat generated through friction. We may, therefore, take it for granted that the lubricant spreads over the surface to be greased, in the form of a thick, oily liquid, filling up the depressions in that surface, and therefore rendering it smoother than would otherwise be the case.

It is a well-known property of all liquids that their compressibility is so slight in fact, that for all practical purposes they may be regarded as incompressible.

If now, one machine part be sliding or rolling on another, and a lubricant is in position between them, the result of the presence of this fluid substance will be to prevent, either wholly or for the most part, the prominences and depressions from catching in each other. Hence the friction will be diminished, to an extent that will be greater in proportion as the machine parts in contact are harder and more smoothly polished, and the more completely the lubricant is fitted for its purpose.

A few lubricants are known which consist of fine powder, and remain in that state under all conditions. They act, however, in just the same way as lubricants which are or become liquid, filling up the inequalities in the surfaces to which they are applied, thus making them smooth, so that the frictional resistance is naturally lessened.

Whatever name a machine lubricant may bear, its purpose is to diminish frictional resistance, and therefore materials best calculated to accomplish this purpose must be used in the manufacture. Sometimes, however, the formulae advanced for the preparation of so-called "improved" lubricants contain ingredients which cannot but increase frictional resistance rather than diminish it.

That the persons recommending such preparations are unacquainted with physical and chemical laws is evident, a trial of such "improved" lubricants soon proving their value.

Although at first sight it may seem an easy matter to make lubricants suitable for different machines, the problem is really a difficult one when we consider all the conditions that a good lubricant is expected to fulfil.

It is only within recent years, during which time the use of lubricants has greatly extended to keep pace with the developments in machinery, that the difficulties attending the manufacture of lubricants have been properly appreciated. That complete success has not yet been attained is demonstrated by the continued appearance of new "improved" recipes, some of which are really the reverse of improvements.

To sum up the properties that a good lubricant should possess, the following are essentials:—

(1) Cheapness, in relation to the cost of the raw materials and the cost of production.

(2) Uniformity and stability of the product: that is to say, each batch of the lubricant must possess the same properties, and must not alter appreciably when stored for some considerable time.

(3) Absence of any corrosive action on the bearings, *i.e.* the chemical properties of the lubricant must be such that it will not corrode, more than inappreciably, the metal parts with which it is brought in contact. In large machines this consideration is not so important, though it is essential in the case of fine and delicately constructed mechanisms such as clocks, sewing machines, scientific instruments, etc.

(4) Uniform consistency at different temperatures. This property is the most important of all in a good lubricant,

but at the same time is the most difficult to obtain. Most of the substances used as lubricants become more fluid as the temperature rises, and, conversely, thicken as it falls.

For every lubricant, however, a certain degree of fluidity, which lies between somewhat narrow limits, is necessary in order that it may properly discharge its functions. If the fluidity is insufficient, lubrication will be imperfect, but if too great, the consumption and waste of material will be excessive, although the lubrication be quite satisfactory.

The difficulties arising from this cause are so great that they cannot be entirely overcome, and in many cases a remedy is sought by using at different seasons lubricants that exhibit the proper degree of fluidity at the temperatures then prevailing. This is particularly the case with machine parts that are exposed to all the fluctuations of temperature inherent to our climate, for example, the axles of carts and railway waggons.

Lubricants may be classified in several ways: (1) According to the ingredients of which they are compounded; (2) according to their physical character; (3) according to the special purposes for which they are intended.

If we regard lubricants with reference to the materials of which they are composed, *i.e.* from the chemical point of view, we find that they include a very large number of substances differing considerably in physical and chemical properties. Since an accurate knowledge of these materials and their properties is indispensable to the manufacturer, we shall consider them fully later.

According to their physical condition, lubricants may be classed respectively as liquid and solid. It is impossible, however, to draw a strict line of demarcation between them. Some are almost as fluid as water while others, at the ordinary temperature, have about the same consistency as a somewhat firm butter. Between these two extremes, however, we find all intermediate stages of consistency, so that it is often difficult to determine whether a lubricant should be classed as a liquid or as a solid. For this reason the system of classification on this basis is of little value.

Again, the purpose for which the lubricants are to be used

may be taken as a basis of classification. Thus we speak of ordinary cart grease, railway grease, machine oil, engine oil, and so on. But even this distinction is arbitrary, since it often happens that a lubricant made for some special purpose can also be used for others.

On this account, therefore, it would seem preferable to classify lubricants according to the materials from which they are compounded, and then subdivide the classes in accordance with the objects for which the lubricants are intended.

Proceeding according to this plan, we may distinguish between the following classes:—

Fatty lubricants, namely, those which consist either of a single fat, whether liquid (oil, train oil) or solid (tallow, palm oil, etc.), or of a mixture of several fats.

Chemical lubricants, namely, such as consist of substances that are artificially produced in large quantities by certain chemical processes, *e.g.* in the manufacture of coal-gas, the refining of petroleum, and various other chemico-technical processes. This class includes the so-called mineral oils, the tar oils, petroleum jelly, the rosin oils, etc. In a certain sense, too, the soaps and emulsions used as lubricants belong to this class.

Mineral lubricants consist simply of certain powdered minerals that are characterised by a greasy appearance and feel (soapstone or steatite, and graphite or blacklead), and by a very low degree of hardness.

Until quite recently, the fatty lubricants were used almost exclusively, and it was only as a consequence of the development of the tar and petroleum industries that the mineral oils and greases were put on the market in large quantities. As we shall see later on, these possess, in comparison with the fats, such great advantages that they have to a very large extent replaced and will probably eventually displace the latter entirely. That this has not already occurred is due on the one hand to the enormous consumption of lubricants, and on the other to the fact that it is not yet possible to produce chemical lubricants capable of meeting satisfactorily all the requirements they are expected to fulfil, as is done by those derived from fats.

CHAPTER II.

SUBSTANCES USED IN THE PREPARATION OF LUBRICANTS.

LUBRICANTS are usually composed of animal, vegetable, or mineral oils, either singly or in admixture, and also in some instances with other products, *e.g.* soaps, steatite, graphite, etc.

The products may be divided into classes according to their origin as follows:—

I. *Animal Fats and Oils.*

Sperm oil.	Hog fat.
Whale oils.	Lard oil.
Dolphin oil.	Tallow (beef).
Porpoise oil.	Tallow (mutton).
Neat-foot oil.	Tallow oil.
Bone oil.	Horse fat.
Bone fat.	

II. *Vegetable Fats and Oils.*

Rapeseed oil.	Hazelnut oil.
Mustard seed oil.	Olive oil.
Almond oil.	Castor oil.
Earthnut oil.	Palm oil.

III. *Treated Oils.*

Blown oils.	Sulphonated oils.
Polymerised oils.	

IV. *Hydrocarbon Oils, etc.*

Petroleum oils.	Paraffin.
Shale oils.	Naphthalene.
Coal tar oils.	Resin.
Lignite oils.	Indiarubber.
Resin oils.	Gutta percha.
Coal tar.	Asphaltum.

V. *Soaps.*

Soda soaps.	Alumina soaps.
Potash soaps.	Magnesia soaps.
Lime soaps.	

VI. *Mineral Substances.*

Graphite.	Sulphur.
Steatite or Talc.	Ammonia.
Soda.	Litharge.
Lime.	Lead acetate.
Mica.	

It has already been mentioned that it is specially important to have a knowledge both of the physical and the chemical properties of the materials of which these products are compounded. In this way alone will it be possible to correctly compound a lubricant, intended to fulfil any special task, with the certainty that it will prove satisfactory.

The Fats and Oils.—It is well known that fats are products of the animal and vegetable kingdoms, and may be divided, according to their consistency, into three groups: (1) Liquid fats, which are also known as oils. (2) Semi-solid fats, of the butter or lard type, namely, such as have, at the ordinary temperature, a soft consistency. Lard and butter, in the animal kingdom, and coconut oil and palm oil, from the vegetable kingdom, belong to this group. (3) Solid fats, or tallow, which are solid and crumbling at low temperatures, and only become soft when heated. This class includes beef tallow, deer fat, mutton fat, etc. It is obvious that this classification only applies in temperate regions since in the tropics semi-solid fats may be fluid, and solid fats semi-fluid.

Since all fats are miscible in any proportions, it is possible, by suitably blending oils with the semi-solid or solid fats, to produce mixtures of any desired consistency and melting point.

Pure fats, to whatever group they may belong, are perfectly inodorous, quite insoluble in water, and are completely indifferent to metals, *i.e.* have no chemical action thereon. It must however be stated that this description applies solely to fats that are perfectly pure; and it is also to be remarked that

Absolutely pure fats are substances that are obtainable only with difficulty, and must be stored with great care if they are not to undergo rapid alteration.

Thus, when a fat is exposed to the air, a marked change is soon observed: the fat becomes darker in colour, assumes a peculiar, disagreeable smell and an irritating flavour—in other words the influence of the air soon turns it rancid. In this process, alterations of a somewhat extensive nature take place in the fat. Free fatty acids are formed together with aldehydes from the glycerin, these being the cause of the rancid taste and smell, in addition to which the acids in rancid fats strongly corrode metals with which they are brought in contact, so that a lubricant containing a rancid fat can hardly be used without danger, especially in fine machines.

Certain liquid vegetable fats—oil—are distinguished by a peculiar behaviour when exposed to the air: they darken in colour, and become progressively thicker, finally setting to a transparent, resinous mass. Oils behaving in this manner are known as *drying oils*. Though drying oils are extremely important in the varnish-making industry, in painting, etc., they are unsuitable for the manufacturer of lubricants, owing precisely to this tendency to gradually thicken and dry. Some oils on exposure to air thicken but do not solidify, these being known as *semi-drying oils*, while oils which do not thicken at all on exposure are known as *non-drying oils*. The oils in the latter class are the only ones suitable for the manufacture of lubricants.

All solid fats become fluid when moderately warmed, furnishing liquids very similar to the ordinary oils. Since all fats, even the solid ones, must be in the fluid state before they can properly discharge their functions as lubricants, a knowledge of the melting points of the solid fats is highly important for our purpose, and we shall therefore give, later, a table showing the melting and setting points of the principal fats. The setting point refers to the temperature at which the melted fat commences to solidify: in many fats this temperature does not coincide with the melting point, but is much lower than the latter.)

When oils are cooled to a low temperature they become thicker as the temperature falls, frequently setting completely to transparent crystalline masses. The fats that are of the consistency of butter or tallow at the ordinary temperature become crumbling and fairly hard when cooled.

The foregoing properties of fats indicate the manner in which various requirements exacted of lubricants can be fulfilled. For machines exposed to high temperatures, special mixtures can be prepared containing fats of high melting point, *eg.* tallow, whilst for use at low temperatures the oils will predominate in the mixture.

The varying consistency of lubricants under the influence of different temperatures renders it necessary, in the case of machines that are exposed to considerable fluctuations of temperature, to employ lubricants of different character for summer and winter use. In Central Europe the difference between the extremes of summer and winter temperature is nearly 75° F., and therefore the grease used for railway axles in summer must be of far higher melting point than that employed in the winter.

In addition to the temperature at which a lubricant is used, the velocity of the motion of the machine parts in question also influences the consistency of the preparation.

That friction is convertible into heat has already been stated; and naturally, the quantity of heat liberated within a unit of time from the machine parts in mutual friction will be greater the higher the velocity of these parts.

Hence if a lubricant suitable for slow-running machines be applied to machine parts in rapid motion, the increased liberation of heat will render the lubricant too fluid, hence it will quickly run out of the bearing. For this reason it must be laid down as a general rule that lubricants of comparatively high melting point must always be used on quick-running machine parts. As an instance of this we find that railway companies use a different grease for the axle boxes of express trains to that used for goods trains, the reason being that the velocity in the former case is greater than in the latter.

Composition of Fats and Oils.—The fats and oils belong

to a group of organic compounds and are very similar to one another in composition, being almost entirely constituted of the glycerides of fatty acids.

Glycerine is a trihydric alcohol $\text{C}_3\text{H}_5\begin{smallmatrix} \text{OH} \\ \text{OH} \end{smallmatrix}$ and is capable

of reacting with one, two, or three molecules of a fatty acid with the elimination of water, forming mono-, di-, and tri-glycerides. The mono- and di-glycerides can be prepared artificially but are not present in natural fats and oils which are composed of tri-glycerides or neutral glyceryl esters which

may be represented by the general formula $\text{C}_3\text{H}_5\begin{smallmatrix} \text{F} \\ \text{F} \end{smallmatrix}$ in which

F represents the radicle of a fatty acid.

Thus triolein, which is present in many oils, has the

formula $\text{C}_3\text{H}_5\begin{smallmatrix} \text{C}_{18}\text{H}_{33}\text{O}_2 \\ \text{C}_{18}\text{H}_{33}\text{O}_2 \\ \text{C}_{18}\text{H}_{33}\text{O}_2 \end{smallmatrix}$ tripalmitin the formula

$\text{C}_3\text{H}_5\begin{smallmatrix} \text{C}_{16}\text{H}_{31}\text{O}_2 \\ \text{C}_{16}\text{H}_{31}\text{O}_2 \\ \text{C}_{16}\text{H}_{31}\text{O}_2 \end{smallmatrix}$ and tristearin the formula $\text{C}_3\text{H}_5\begin{smallmatrix} \text{C}_{18}\text{H}_{35}\text{O}_2 \\ \text{C}_{18}\text{H}_{35}\text{O}_2 \\ \text{C}_{18}\text{H}_{35}\text{O}_2 \end{smallmatrix}$ the

two latter being contained in solid fats.

The fats and oils are, however, composed not of one glyceride alone but usually of several glycerides which in most cases are so closely associated that it is difficult and indeed almost impossible to separate them entirely by physical means. It is therefore believed that fats and oils are largely composed of "mixed glycerides" in which the hydrogen atoms in the molecule of glycerine are replaced by different fatty acids instead of a single acid.

Several of these "mixed glycerides" have been isolated and examined, and they show very well marked properties so that their existence in fats and oils may be assumed to be proved.¹

The most commonly occurring tri-glycerides are the following:—

Trilaurin. $\text{C}_3\text{H}_5(\text{C}_{12}\text{H}_{23}\text{O}_2)_3$.—This occurs in coconut

¹ For a description of these see Lewkowitsh "Chemical Technology of Oils, Fats and Waxes," 1913, Vol. I., pp. 30-37.

fat and in laurel oil. It is a solid crystalline product melting at 45°C .

Tripalmitin. $\text{C}_3\text{H}_5(\text{C}_{16}\text{H}_{31}\text{O}_2)_3$ is the characteristic constituent of palm oil which is composed almost entirely of tripalmitin and free palmitic acid. It is also present in other solid fats. Palmitic acid crystallises in needles melting at 65°C .

Tristearin. $\text{C}_3\text{H}_5(\text{C}_{18}\text{H}_{35}\text{O}_2)_3$ is a constituent of many solid fats, particularly in tallow. It crystallizes in needles having a melting point of 72°C .

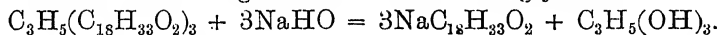
Triolein. $\text{C}_3\text{H}_5(\text{C}_{18}\text{H}_{33}\text{O}_2)_3$ is present in most non-drying oils, also in association with palmitin and stearin, in solid fats. Oleic acid is liquid at the ordinary temperature but solidifies at -4°C .

Trierucin. $\text{C}_3\text{H}_5(\text{C}_{22}\text{H}_{41}\text{O}_2)_3$ is present in rapeseed oil. It is a solid substance melting at 31°C .

Triricinolein. $\text{C}_3\text{H}_5(\text{C}_{18}\text{H}_{33}\text{O}_3)_3$ is the chief constituent of castor oil and is liquid. Ricinoleic acid being a hydroxylated fatty acid ($\text{C}_{18}\text{H}_{33}\text{O}_3 \cdot \text{OH}$) triricinolein differs in constitution from all the other natural fats and oils. To this fact may be ascribed its peculiar properties, *i.e.* extremely high viscosity and solubility in alcohol.

Fatty Acids.—Free fatty acids are present to a greater or lesser extent in all fats and oils, for instance palm oil may contain as much as 80 per cent. of free fatty acids whereas lard may not contain more than 1 per cent. The free fatty acids are formed either by the action of natural enzymes or *lipases* as they are termed, as in castor oil; by fermentation as in olive oil and palm oil; or by the action of bacteria in crude fats such as tallow. Rancidity is also due to bacteria and oxidation resulting in the production of aldehydes which can readily be detected. The remedy for these troubles is to thoroughly sterilise the material by heat before the fat or oil is extracted.

Fatty acids are formed by saponifying the fat or oil with caustic soda or caustic potash by the aid of heat in which case soaps of the alkalies are produced. Thus from olein and caustic soda we get sodium oleate and glycerine:—



Under proper conditions the whole of the fat will be converted into soap which dissolves in the liquid. On adding slight excess of sulphuric acid to this solution the soap is decomposed and a precipitate of fatty acids forms which may be either liquid or solid according to its melting point.

The fatty acids which have been obtained from natural fats and oils and waxes have been divided into five classes according to their composition. These are given in the following tables:—

1. *Saturated Acids of the General Formula, $C_nH_{2n}O_2$ (Acetic Series).*

	Formula.	Melting Point.	Origin.
Butyric acid . . .	$C_4H_8O_2$	-6.5°	Butter fat.
Valeric acid . . .	$C_5H_{10}O_2$	solid at -18°	Dolphin and Porpoise oils.
Caproic acid . . .	$C_6H_{12}O_2$	-8°	Butter fat.
Caprylic acid . . .	$C_8H_{16}O_2$	16.5°	Butter, coconut and palm-nut oils.
Capric acid . . .	$C_{10}H_{20}O_2$	31.3°	Goat fat, butter.
Lauric acid . . .	$C_{12}H_{24}O_2$	43.6°	Laurel oil.
Myristic acid . . .	$C_{14}H_{28}O_2$	53.8°	Nutmeg oil.
Isocetic acid . . .	$C_{15}H_{30}O_2$	55°	Curcas oil.
Palmitic acid . . .	$C_{16}H_{32}O_2$	62.6°	Most fats, palm oil.
Stearic acid . . .	$C_{18}H_{36}O_2$	69.3°	Most fats.
Arachidic acid . . .	$C_{20}H_{40}O_2$	77°	Earth-nut oil.
Behenic acid . . .	$C_{22}H_{44}O_2$	83°	Oil of ben.
Lignoceric (carnaubic) acid	$C_{24}H_{48}O_2$	80.5°	Earth-nut oil.
Cerotic acid . . .	$C_{26}H_{52}O_2$	77.8°	Beeswax.
Melissic acid . . .	$C_{30}H_{60}O_2$	91°	Beeswax.

2. *Unsaturated Acids (with Double Bond) of the General Formula, $C_nH_{2n-2}O_2$ (Oleic Series).*

	Formula.	Melting Point.	Origin.
Tiglic acid . . .	$C_5H_8O_2$	64.5°	Croton oil.
Hypogoeic acid . . .	$C_{16}H_{30}O_2$	33.0°	Earth nut oil.
Phytetoleic acid . . .	$C_{18}H_{34}O_2$	30°	Sperm oil.
Oleic acid . . .	$C_{18}H_{34}O_2$	6.5°	Most oils, olive oil.
Rapic acid . . .	$C_{18}H_{34}O_2$	—	Rape oil.
Doeglic acid . . .	$C_{19}H_{36}O_2$	—	Arctic sperm oil.
Jecoleic acid . . .	$C_{19}H_{36}O_2$	—	Cod-liver oil.
Gadoleic acid . . .	$C_{21}H_{40}O_2$	24.5°	Cod-liver oil.
Erucic acid . . .	$C_{22}H_{42}O_2$	33°	Rape oil.
Brassicidic acid . . .	$C_{22}H_{42}O_2$	65°	Rape oil.

3. *Unsaturated Acids (with Triple Bond) of the General Formula, $C_nH_{2n-4}O_2$ (Linolic Series).*

	Formula.	Melting Point	Origin.
Linolic acid . . .	$C_{18}H_{32}O_2$	Fluid at -18°	Linseed oil and other drying oils.
Elæomargaric acid . .	$C_{19}H_{32}O_2$	47°	Chinese wood oil.

4. *Acids of the General Formula, $C_nH_{2n-6}O_2$ (Linolenic Series).*

	Formula.	Melting Point.	Origin.
Linolenic acid . . .	$C_{18}H_{30}O_2$	—	Linseed oil.
Isolinolenic acid . .	$C_{19}H_{30}O_2$	—	Linseed oil.

5. *Hydroxy Acids of the General Formula, $C_nH_{2n-2}O_3$.*

	Formula.	Melting Point.	Origin.
Ricinoleic acid . . .	$C_{18}H_{34}O_3$	4°	Castor oil.

ALCOHOLS.

The following alcohols are present in fats and waxes in combination with fatty acids:—

1. *Trivalent Alcohol of the Formula, $C_nH_{2n+2}O_3$.*

	Formula.	Melting Point.	Origin.
Glycerol (glycerine) . .	$C_3H_8O_3$	$20^\circ C.$	In all fats.

2. *Monovalent Alcohols of the Fatty Series with the General Formula, $C_nH_{2n+2}O$.*

	Formula.	Melting Point.	Origin.
Cetyl alcohol . . .	$C_{16}H_{34}O$	$50^\circ C.$	Spermaceti.
Octodecyl alcohol . .	$C_{18}H_{38}O$	$59^\circ C.$	Spermaceti.
Ceryl (iso-ceryl) alcohol .	$C_{26}H_{54}O$	$79^\circ C.$	Chinese wax.
Myricyl (melissyl) alcohol .	—	$85^\circ C.$	Beeswax.

The following alcohols are also present in fats and waxes in a free state :—

3. *Monovalent Aromatic Alcohols (Sterols).*

	Formula.	Melting Point.	Origin.
Cholesterol . . .	$C_{27}H_{46}O$	150°	In all animal fats, particularly wool fat.
Isocholesterol . . .	$C_{27}H_{46}O$	137°	In all animal fats, particularly wool fat.
Phytosterol (Sitosterol) . .	$C_{27}H_{46}O$	137°	All vegetable fats.

The sterols are present only in very small amounts in fats and oils, and are found in the unsaponifiable matter which in most fats and oils does not usually amount to more than 1 per cent. Nevertheless these substances are very characteristic so that they serve in analysis as a means of dis-

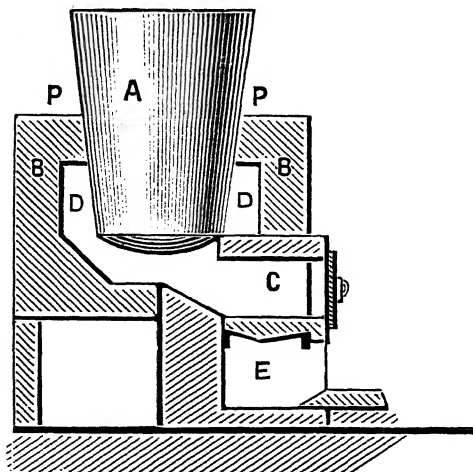


FIG. 1.—Fire heated fat rendering pan.

tinguishing animal from vegetable oils and also for detecting adulteration. The unsaponifiable matter in waxes consists of alcohols of the fatty series which are present to the extent of about 50 per cent. Sperm oil is a fluid wax and not truly an oil seeing that it contains no glycerine. Sperm oil contains 40 to 44 per cent. of unsaponifiable matter consisting

of alcohols the composition of which has not yet been determined. Certain shark-liver oils contain moderately large quantities of unsaponifiable matter, consisting of hydrocarbons. Both saturated and highly unsaturated hydrocarbons have been found in many Japanese shark oils (Tsujimoto).

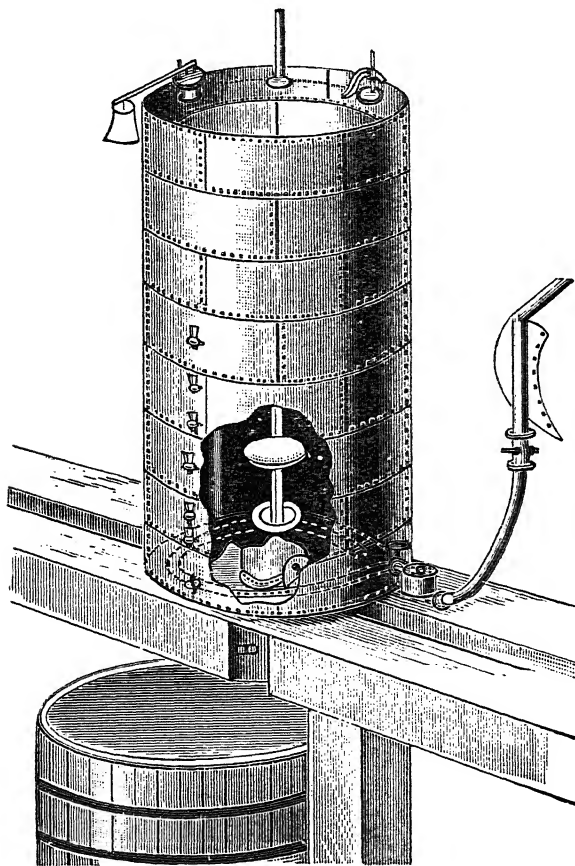


FIG. 2.—Boiler for melting tallow under pressure.

Preparation of Fats and Oils.—The animal fats such as tallow and lard are rendered either by fire heat in an open pan, Fig. 1, or in a boiler with open steam under pressure, Fig. 2.

The method of melting by steam is to be preferred, since it yields a purer and whiter fat and one without odour. The

residue or "greaves" are pressed in order to remove as much fat as possible.

Bone fat is obtained either by boiling the bones with water under pressure in a pan similar to that shown in Fig. 3 or by the solvent extraction process, in which volatile fat solvents are employed, *e.g.* petroleum benzine, carbon bisulphide, or carbon tetrachloride.

For the extraction of vegetable oils the seeds are first crushed between rolls and then packed in bags which are placed between the plates of a hydraulic press, Fig. 4, in

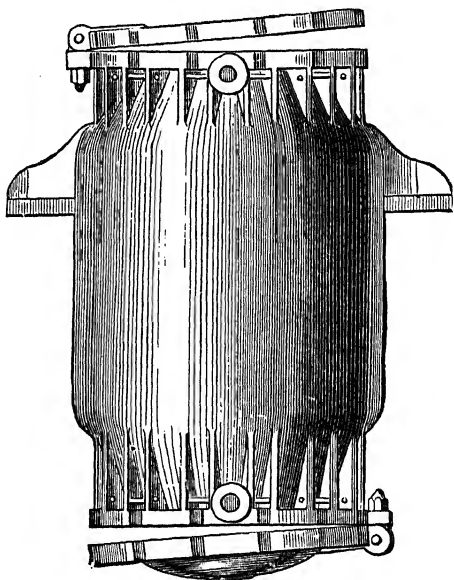


FIG. 3.—Digester for extracting fat from bones.

which very considerable pressure is applied. The oil oozing out from the meal passes along gutters at the sides of the plates down to a trough through which it passes to the storage tanks below.

Another method of extracting oils from seeds is the solvent extraction process. This has come very largely into practice in recent years since it extracts almost the whole of the oil and therefore gives a much higher yield than can be obtained by pressure. In the solvent extraction process the crushed seeds are fed into large tanks, which can be closed and in

which the material is subjected to the action of a volatile solvent, being at the same time heated by steam or the hot vapour of the solvent. The liquid containing the fat in

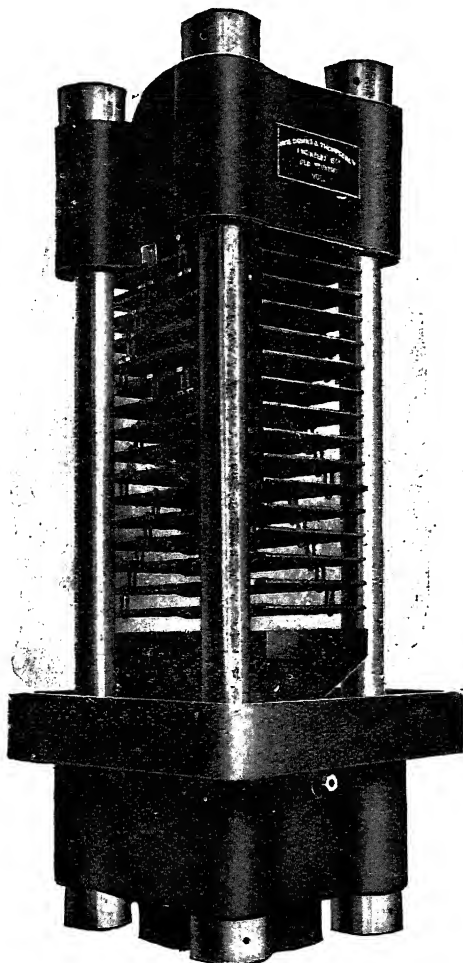


FIG. 4 —Hydraulic press for oil seeds (Rose, Downs & Thompson, Ltd.).

solution is run into a boiler, in which the solvent is distilled off and, being condensed, is again ready for use, while the fat is run out of the boiler to make room for another charge. The solvents employed are those which are easily volatilised

and which possess no odour, *i.e.* purified petroleum benzine, carbon bisulphide, or carbon tetrachloride.

Figs. 5 and 6 show the solvent extraction plant made by George Scott & Son, Ltd.

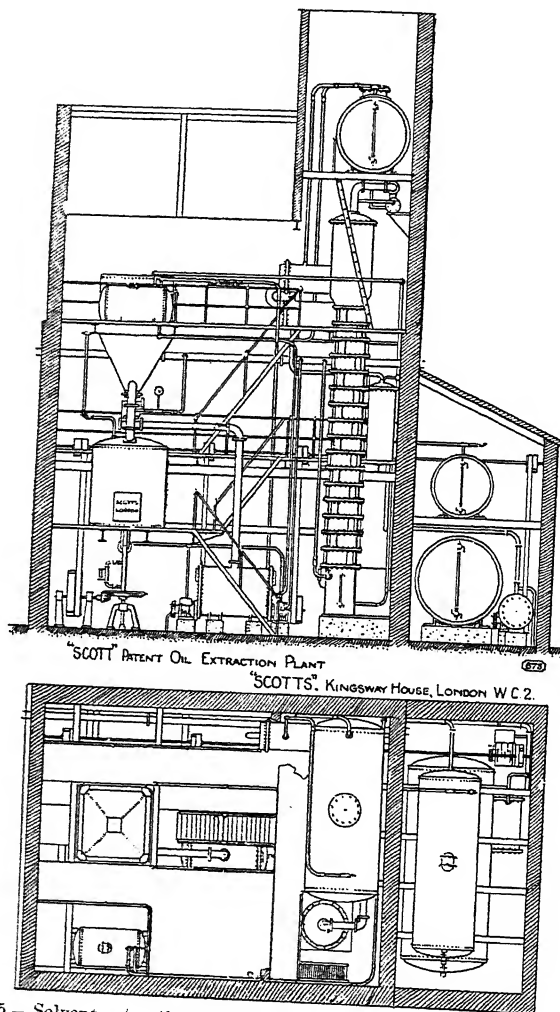


FIG. 5.—Solvent extraction plant (George Scott & Son, Ltd., London).

Purification of Oils and Fats.—The oils and fats prepared as described are usually more or less impure, containing varying amounts of colouring matter in solution, and water,

mucilaginous matter, and suspended cellular particles, so that

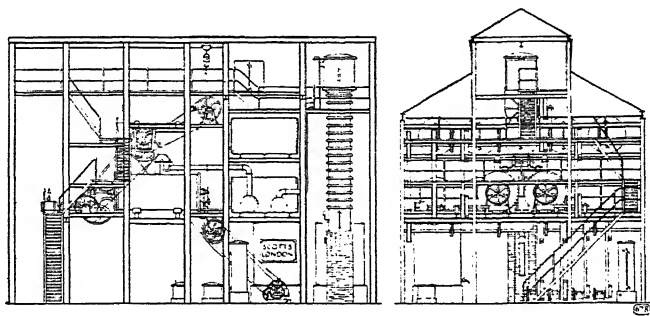


FIG. 6.—Solvent extraction plant (George Scott & Son, Ltd., London).

they require to be refined. The refining processes differ according to the nature of the oil and its quality.

Usually oils are allowed to stand for some time in large iron tanks in order that water and suspended matters may subside. The separation of the clear oil is rendered easier by having a cone-shaped arrangement, Fig. 7, in the bottom of the tank into which the impurities settle while the clear oil is run off from a higher level.

As this method of purification occupies considerable time, in some works the oil is immediately put through a filter press, Fig. 8, which retains the suspended material while the clear oil passes through. Sometimes Fuller's oil is added to the oil, which helps to separate the suspended matter and also reduces to some extent the colouring matter.

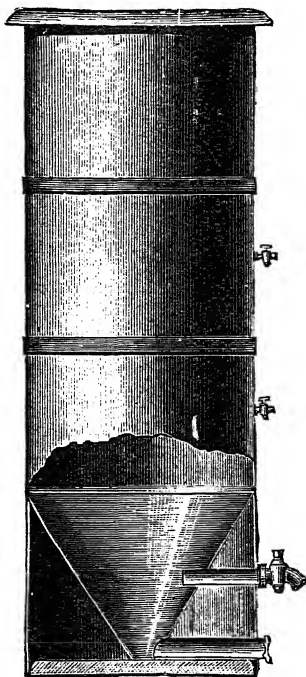


FIG. 7.—Settling tank for clarifying oils.

Solid fats are treated in a similar manner, but, in order to keep them fluid, it is necessary that the whole of the plant

employed be kept at a temperature somewhat above their melting points for which purpose the settling tanks are steam jacketed.

In some cases it is necessary to further purify the oils and fats before they can be used. This purification is usually carried out by chemical treatment, the agents most often employed being sulphuric acid and caustic soda, but in some cases, *i.e.* highly coloured fats, ozone, potassium bichromate and sulphuric acid and other oxidising agents are employed.

The purification is usually carried out in large wooden vats lined with sheet lead, these being provided with stirring gear, open and closed steam coils and draw-off cocks. In treating the oil with sulphuric acid about 2 per cent. of the

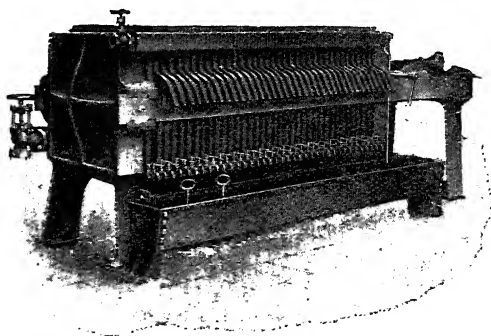


FIG. 8—Filter press for clarifying oils (S. H. Johnson & Co., Ltd.).

latter on the weight of the oil is employed diluted with an equal volume of water, this is stirred into the oil and the latter steamed, then washed with hot water till free from acid and the last traces of water driven off by using the steam coil. The sulphuric acid destroys the mucilaginous and finely divided organic matter in the oil but does not affect the free fatty acids. For this reason oils refined by the acid process are not as a rule suitable for use as lubricants, besides which they may contain traces of mineral acid due to insufficient washing which would be extremely detrimental to any metallic parts to which the oil might be applied.

The treatment with caustic soda is carried out similarly, but in this case sufficient of the alkali is added to more than neutralise the whole of the free fatty acids, which are therefore

dissolved out and pass into the aqueous layer in the form of soaps, so that the purified oil is entirely free from fatty acids. Oils treated by the alkali process are therefore very well suited for use as lubricants, and provided the alkali has all been washed out they usually keep good for a very long period. The removal of the fatty acids as soaps leads to a loss of oil and usually presents another serious drawback, the soap solution forming an emulsion with a considerable proportion of the oil which is usually extremely difficult to break up. This emulsion is, however, removed before washing and is used in soap making, or broken with an acid and the fatty matter sold as soap stock.

REFINING OILS FOR LUBRICATING PURPOSES.

The Sulphuric Acid Process.—The ordinary method of refining oils is with sulphuric acid. When a crude oil, as it issues from the press, is intimately mixed with sulphuric acid, a strong reaction is produced, the time taken for this to ensue depending on the amount of acid used.

At first the temperature of the mixture rises considerably, and the oil assumes a greenish tinge, the colour of the mixture gradually deepening through brownish green to brown, and finally to black.

The cause of this colour change is that the sulphuric acid first attacks and destroys the greenish or yellowish colouring matter found in most oils, and especially in the rape and olive oils frequently used for lubrication. At the same time the accompanying cell substance, vegetable mucilage, and other foreign matters undergo alteration, being gradually decomposed and carbonised by the dehydrating action of the sulphuric acid.

The very finely divided carbon thus produced causes the gradual change of colour from brown to black. During the operation, which must be carried on in lead-lined vessels, as the acid would corrode other materials, the mixture is constantly stirred, and in many works the reaction is assisted by heat. As all chemical processes are accelerated by warmth, so also the destruction of the foreign admixtures in the oil is

effected more rapidly the higher the temperature of the oil under treatment.

It is advantageous to heat the oil by passing steam through a leaden coil in the vat, thus raising the temperature to about 140°-160° F. The higher the temperature of the oil, the sooner is the refining process over, and the smaller the amount of acid required.

This last factor is a very important one for the manufacturer of lubricants, not only on account of the saving of acid, but also because it limits the direct action of the sulphuric acid on the oil itself.

The quantity of acid used may rise as high as 3 per cent. of the oil to be refined. It is run, in the form of a thin stream, into the warmed oil, and an attempt is made to secure the most intimate possible admixture of the oil and acid, by keeping the stirrers running at high speed. After the operation the liquid is left to rest, when it soon separates into two layers, the oil, which is much thinner than before and is partially bleached, floating on the top, whilst underneath it lies the acid, which has become diluted by the absorption of water and is coloured a deep black by the finely divided carbon in suspension.

The oil is syphoned off from the acid layer, and is freed from accompanying traces of acid by washing. In this operation it is necessary to pour the oil, as a thin stream, into warm water, which is kept in rapid motion by stirrers, the oil being afterwards separated from the water and put through the same treatment again. By careful and repeated washing it is possible to purify the oil to such an extent that no trace of free sulphuric acid can be detected by even the most delicate chemical tests.

This, the ordinary practice in oil refineries, yields an oil that is perfectly clear, thin, and pale in colour: but it possesses one drawback that forms an important obstacle to its use for lubrication. Although the sulphuric acid has been removed by careful washing, the oil is never neutral, but always contains a considerable quantity of free fatty acids which would strongly corrode the metallic machine parts.

This peculiarity is due to a reaction of the sulphuric acid

on the constituents of the oil itself. Like most fats, oils consist of a compound of glyceryl oxide with various fatty acids, the most usual of these being stearic, palmitic, and oleic acids.

When a fat or oil is treated with caustic alkalis, caustic potash, caustic soda, quicklime, or lead oxide, the glyceryl oxide combines with water to form glycerine, which is eliminated, whilst the fatty acids combine with the base (soda, potash, lime, or lead) to furnish the compounds known as soaps.

When sulphuric acid is brought into contact with fats or oils, a process analogous to saponification occurs, which is therefore, though erroneously, known as saponification by sulphuric acid, more properly as hydrolysis. The oil is decomposed in such a manner that glycerine separates out, the sulphuric acid entering into combination with the oleic acid.

This compound of sulphuric acid and oleic acid, however, is unstable and is readily converted into sulphuric acid and oleic acid by the action of a large volume of water. The sulphuric acid passes away in the water, but the oleic acid dissolves in the oil imparting acid properties to it. Machine parts lubricated with such an oil soon reveal traces of the chemical action of the fatty acids present.

Hence, in order to refine oils intended for lubricating purposes, another method must be adopted than that which is suitable for lamp oils, etc. With this idea in view the quantity of sulphuric acid is reduced to a minimum, not more than 1 per cent. on the weight of the oil to be purified. With such a small quantity of acid the refining process is greatly retarded, and must therefore be accelerated by warmth. The following method on these lines has always given excellent results with a minimum quantity of sulphuric acid.

The freshly pressed oil is placed in a large lead-lined vat, fitted with a steam coil and stirrers. By means of high-pressure steam the oil is quickly heated to the boiling point of water, whereupon the sulphuric acid is run in. The stirrers are kept running at good speed for a considerable time, until the whole of the liquid has become black. As soon as this is noticed, the steam is turned off, but the stirrers are kept moving half an hour longer.

The dark-coloured liquid is at once transferred to another vat, to be washed with water, the mixture of oil and water being stirred until all the former is in. This done, the stirring is stopped, whereupon the liquid separates into two layers, the oil floating on the top, whilst the lower one consisting of water acidified with sulphuric acid, is of a dark colour, owing to finely divided carbon. This washing process is repeated, a third treatment being given if necessary, but no interval should be allowed between them.

This short treatment with sulphuric acid, followed by a quick separation of the acid and oil by washing, limits the action of the acid to the destruction of the foreign matters present, without allowing it to extend to the alteration of the oil and consequent formation of oleic acid. As a rule, two washings after the acid treatment will suffice to free the oil completely from all traces of acid.

The entire removal of the sulphuric acid from the oil is also necessary, since this acid has an even more energetic action on metals than oleic acid. The freedom of the oil from sulphuric acid is detected by shaking up the liquid with a little barium chloride solution. If the oil remains unchanged, no free sulphuric acid is present; but if it becomes opalescent or assumes a whitish tinge, this is a proof that the oil contains sufficient free sulphuric acid to act injuriously on the metal of any machine it may be used to lubricate. In order to make quite sure, however, the barium chloride solution should have first received an addition of a few drops of hydrochloric acid, this being necessary to prevent the precipitation of any other barium salt which might be mistaken for the sulphate.

In addition to the sulphuric acid method of refining, which though somewhat troublesome is still the best, various others have been proposed. Of these, attention is best merited by those in which the crude oil is treated with a solution of tannin, with caustic soda or with zinc oxide or magnesia and litharge.

Refining with Tannin.—In this method the oil is heated to the boiling point of water, and intimately mixed, by stirring, with about 5 per cent. of a strong solution of tannin.

This solution is prepared by boiling fresh oak bark with its own weight of water for half an hour, and straining the decoction through a fine cloth.

Though the tannin partially precipitates the foreign substances present in the oil, it does not effect complete separation of the whole, the colouring matter of the oil, for instance, being left unchanged, so that the refined oil is always dark coloured, which lowers its value from a commercial point of view.

Refining with Caustic Soda.—The method of refining oil with caustic soda is based on the principle that very strong soda lye, when brought into contact with oil for a short time only, completely destroys the foreign impurities while at the same time not attacking the oil to any appreciable extent.

The oil to be refined is placed in a large pan, and after being heated to the boiling point of water, is treated with an addition of $2\text{--}3\frac{1}{2}$ per cent. (at most) of highly concentrated caustic soda lye, with constant stirring.

Within a short time the liquid becomes very turbid, frothing considerably and throwing up a flocculent scum, which, however, soon falls to the bottom, leaving the clear oil floating on the surface.

Since the mucilaginous matters are partly dissolved in the lye and partly coagulated, in a form resembling coagulated albumin, they are easily separated from the refined oil.

The best way of effecting this separation is by means of a flannel filter, the rough side of which is turned inwards. In this way the oil is quickly obtained as a clear liquid.

In this method also, which is most frequently employed for refining rape oil, the minimum quantity of the refining agent (caustic soda) should be used, since a large quantity would entail an excessive waste of oil.

Thus, if more of the soda be used than is necessary for eliminating the foreign impurities, the alkali will act directly on the oil converting a portion of it into soap, which remains in solution in the liquid separated from the oil. This is not of material importance in the case of oil refineries connected with soapworks or those able to dispose of the spent lye to a soap boiler, since in such event the soap solution

can be utilised ; otherwise the losses in refining will be found extremely high.

It is impossible to make a definite statement as to the smallest quantity of lye that will suffice for a given oil, since this depends on the amount of impurities present. Oil coming fresh from the press, especially from a powerful hydraulic press, will naturally contain a larger proportion of foreign substances than that which has been obtained by moderate pressure and then stored for some time, so that in the former case a larger quantity of soda will be needed than in the latter. The only way of ascertaining the minimum is by practical experience, making trials with small quantities of the oil to be refined.

The advantages of the caustic soda method are not unimportant, the operation proceeding quickly and satisfactorily, and yielding an absolutely acid-free product, every trace of free fatty acid being eliminated by the alkali.

Provided the operation be performed in a wooden vat heated by steam, or in a clean iron pan if steam is not available, the oil will not darken in colour. On the other hand, copper pans should be avoided, the metal being attacked by the alkali, the oil being coloured green by the dissolved copper.

Caustic potash may be used in place of caustic soda, with the same result but is not often employed since it is much dearer, the solid commercial caustic being used. The best way to prepare the highly concentrated lye is by placing the lumps of caustic soda in an iron vessel, and covering them with an equal weight of water. Solution takes place very quickly, the liquid becoming very hot. Owing to the corrosive action of these highly concentrated lyes, they require very careful handling, since a drop falling on the skin will lead to soreness, as it has a destructive action.

The sole objection that can be urged against the method of refining with caustic soda is that the oil is not bleached, but retains its original colour, and in some cases may even become darker, especially when the proportion of caustic lye is large.

Although the colour of a lubricating oil has no influence

on its lubricating properties, it is none the less desirable to obtain it with as light a colour as possible, since this, in conjunction with brightness, is regarded by the consumer (and not altogether without reason) as an indication of careful refining.

In this connection the sulphuric acid method, when properly carried out, is highly serviceable, furnishing a product of exceptional quality. Other methods have been proposed with the same object in view, but with only partial success.

After numerous experiments in this direction, the author has ascertained that two methods are really useful, but furnish dissimilar products. These are the methods employing either zinc oxide or litharge.

Refining with Zinc Oxide.—In this method, which is chiefly employed for rape oil, the crude oil is first treated, as already described, with a very small quantity of sulphuric acid. The oil becomes dark coloured, passing from brown into black, separates from the acid, and is repeatedly washed with hot water, until it ceases to give a precipitate with barium chloride.

As already mentioned, in this treatment the action of the acid on the oil results in the formation of a compound of sulphuric and oleic acids, which is decomposed into these constituents again when treated with a large volume of water. Consequently the refined oil invariably contains a certain quantity of free oleic acid, which would strongly corrode the machine parts; and to remove this oleic acid advantage is taken of the property of zinc oxide of combining with the acid in question to form an insoluble compound, zinc oleate.

Zinc oxide is obtainable at a low price in commerce as zinc oxide white, a heavy white pigment. The quantity required for the purpose in view is 1 per cent. of the weight of the oil under treatment. To ensure the most complete diffusion of the zinc oxide through the oil, the former is first stirred up with three to four times its own weight of the oil, until a white, milky fluid is obtained, which is then run into the bulk of the oil, with constant stirring.

After remaining at rest for several hours, the greater portion of the unaltered zinc oxide and the zinc oleate will have sunk to the bottom, but as it would take too long to wait for complete clarification, the oil is filtered.

It has also been proposed to place the oil in a vessel containing zinc turnings or scraps. True, these soon become coated with a white film of zinc oleate, and the oil is purified; but it is very difficult to obtain a clean surface on the metal again, to fit it for treating the next charge of oil, and therefore the treatment of the raw oil with zinc oxide is preferable.

When the operation has been carefully performed the oil refined by the zinc white process possesses, in a high degree, all the necessary properties of a good lubricating oil; it is very pale in colour, and can be obtained almost colourless, if the oil was originally pale; it is also inactive towards metals, and will not become acid, even after prolonged standing in the air. Being comparatively fluid it is very suitable for oiling fine machine parts, since it does not thicken when the machine is left unused for some time.

To obtain a suitable lubricant for coarser machines, the rape oil must be mixed with tallow, palm oil, or some other fat capable of rendering it less fluid.

Magnesia or oxide of magnesium can be used for refining in place of zinc oxide, the process of treatment being exactly as described above. Oils refined by this process are particularly suitable for lubricating watches, clocks and very light machinery.

Refining with Litharge.—When lead oxide is used for refining, the method adopted is, in principle, precisely the same as with zinc oxide. There is, however, some difference in the behaviour of the two oxides, the resulting lead oleate being less easily separated than the zinc compound, since it remains dissolved in the oil. The latter, it is true, is perfectly free from any trace of free acid, but is rendered more viscous by the presence of the lead oleate; and in fact, if more than the necessary amount of lead oxide be used, and the reaction be assisted by heat, the oil may thicken to the consistency of lard or soft butter. This change is usually

observed when the oil contains $2\frac{1}{2}$ to 3 per cent. of lead oxide.

The soft mass formed by treating rape oil with litharge in this way makes excellent lubricants, which are specially prepared for certain purposes.

Colza oil (Fr. Huile de Colza; Ger. Kohlsaatoel) is refined in the same way as rape oil; in fact these two oils are very similar in their properties, though they can be readily distinguished by an expert.

Some considerable confusion exists in commerce respecting the nomenclature of rape and allied oils. One kind, known as Rubsen oil, is obtained from the seeds of *Brassica napobrassica*; whilst a second grade, rape oil proper, is derived from the seeds of winter or summer rape, the respective plants being *Brassica napus oleracea* and *Brassica napus praecox*. Colza oil is from the seeds of *Brassica campestris*.

Refining Olive Oil and Rape Oil.—Since petroleum has displaced nearly all the fatty oils for lighting purposes, olive oil is obtainable at prices enabling it to be used for lubrication.

The process of refining this oil is exactly the same as that already described for rape oil. The sulphuric acid method is the one generally adopted, followed by an extremely careful washing with water, hot at first, and afterwards at the ordinary temperature. The zinc oxide or litharge treatment is less often practised. It would seem that the combination of the oleic acid and glycerine is more stable in the case of olive oil than in rape oil; at least this conclusion is deducible from the fact that, when small quantities of sulphuric acid are used with a neutral oil the oil is thoroughly refined without any detectable traces of free oleic acid being formed.

Olive oil is also often used for lubricating the finest and most delicate machinery, for example as a clockmaker's oil, and for this purpose it is usually desired to be perfectly colourless. The sulphuric acid method of refining, however, yields a product that is coloured golden yellow at least, just like the best quality oil for culinary purposes, the colouring matter of the oil resisting the action of the acid almost completely.

Nevertheless, it is not difficult to obtain even the common qualities of olive oil in a perfectly colourless condition; for though the colouring matter resists the action of chemical reagents, it can be completely destroyed by protracted exposure to light, especially direct sunlight, so that the oil can be obtained as a perfectly water-white liquid.

The bleaching of olive oil, which is only necessary in case it is to be used for the finest lubricants, can be effected by keeping it in vessels of clear white glass, that are tightly closed and set in a sunny place. The smaller the bottles, the shorter the time required for complete bleaching.

Olive oil is in every respect an excellent lubricant. When properly refined it will keep for several years before commencing to thicken. (It may be remarked here that the technical name for this thickening of lubricating oils, namely, "resinification," is erroneous, the formation of resin occurring solely in the case of ethereal oils.) Olive oil possesses the additional valuable property that when of good quality it contains very little free oleic acid, and that the mucilaginous impurities present are readily destroyed by refining.

Any fine, non-drying oil can be used as a lubricant provided the price is not prohibitive. Manufacturers should endeavour, in their own interests, to ascertain whether other oils, in addition to those already mentioned, can be utilised for this same purpose on an extended scale. Ground-nut oil, or arachis oil, clearly exhibits the properties of an excellent lubricant, and is also obtainable in commerce at relatively low prices; but though it has been used for this purpose, its application has not been on any large scale.

The same properties are also possessed by sesamum oil and beechnut oil. The latter, for instance, could be produced in very large quantities in Germany, where the beech is one of the chief forest trees. The author desires particularly to direct the attention of lubricating oil manufacturers to the oil obtained from beechnuts in the ordinary manner, since his own experiments, conducted on an extensive scale, show this oil to be admirably adapted for the purpose; and the raw material, beechnuts, could be readily obtainable in large quantities.

PROPERTIES OF THE FATS AND OILS.

I. *Solid Fats*.—Strictly speaking, the solid fats may be divided into two groups: the firmer kinds, or tallows, distinguished by a certain degree of hardness and high melting point; and the softer, butter-like fats, or lards, including also certain vegetable fats, which, though solid at ordinary temperature, are nevertheless usually referred to as oils. Examples of these last named are coconut oil and palm oil.

Tallow is the friable fat more particularly found in the carcasses of ruminating animals. There are two chief commercial varieties: beef tallow and mutton tallow. The characteristic feature of tallow, its friability, decreases in proportion as other fats are mixed with it; and, to the expert, this friability of tallow affords a good criterion of purity. The purification of crude tallow is now pursued on a large scale in several factories, large quantities of the raw material being also shipped of late years from South America (beef tallow) and Australia (mutton tallow).

Tallow has about the highest melting point of any animal fat. It is impossible to give exact figures of the melting point of the tallows, since this value alters during storage, the older the tallow the higher the melting point as a rule. Some tallows melt at 42° C. (108° F.), whilst others do not become fluid below 50° C. (122° F.).

The specific gravity of tallow varies from 0.943 to 0.952 at 15° C., saponification value 193 to 200, and iodine value 35.4 to 47.5.

Moreover, the melting point of tallow can be raised by separating the more fluid portion. When pure tallow is melted and the resulting liquid is stirred until it sets again, a translucent mass is obtained which, when subjected to heavy pressure, exudes a certain quantity of an oily mass known as tallow oil, leaving a more solid fat known as beef stearin behind. The oil is used either in soapmaking or in the manufacture of liquid lubricants. This method of raising the melting point of tallow may be advantageously employed for the preparation of solid lubricants for use in very hot localities—*e.g.* in the tropics.

Tallow is frequently used in the preparation of lubricants that are required to remain solid at the ordinary temperature; and it is often added to compound lubricants with the object of raising their melting point. Manifestly, therefore, the tallow with the highest melting point will be the most useful grade for the manufacturer of lubricants.

The higher the melting point of the tallow, the smaller the quantity needed to impart the desired increased consistency to a lubricant, and on this account, tallow freed from tallow oil is recommended.

In the form in which it comes from the butcher, tallow is unsuitable for the manufacture of lubricants; it must first be put through a special process of purification, in order to free it from the accompanying cellular tissue, blood and scraps of flesh. As already mentioned, the purification of large quantities of crude tallow forms a branch of industry, that of the tallow melter; but the operation can also be performed easily on a smaller scale by anyone.

There are several methods of carrying out the purifying process, the simplest being that known as "rendering". This consists in cutting up the tallow into small lumps and melting these, along with water, in a pan over an open fire, or better still by steam. The skin and other impurities accompanying the tallow, collect on the surface of the molten mass in the form of "greaves," which are then skimmed off and the purified fat left to set hard. Though this rendering process is a very simple one, it furnishes only a relatively low yield of tallow, not more than 80-82 per cent., even when the greaves are thoroughly pressed.

A larger yield is obtained by melting the tallow along with dilute sulphuric acid, 1 part of this acid and 20 of water being taken to each 100 parts of tallow. Under the combined influence of the acid and heat, all the particles of skin, etc., are dissolved in a few hours, thus purifying the tallow. The latter is obtained in a perfectly pure condition by afterwards remelting it with water. The melting must be performed in lead-lined wooden vats, by steam heat, since iron or copper vessels would be affected by the acid.

Another very useful method of purifying tallow is with the

aid of caustic soda. Three thousand parts of tallow are melted along with 2000 parts of water containing 5 parts of caustic soda in solution. Since the soda possesses the property of combining with the free fatty acids, to form soaps, this method is particularly applicable when the tallow is very old and rancid. Moreover, this method, which in addition is the cheapest of all, has the advantage of entirely freeing the fat from acids.

Unless the manufacture of lubricants is carried out on a very large scale, it is preferable to buy the tallow from a refiner, though, for experimental purposes, it may become necessary to undertake the purifying process oneself. In this case it is best to employ the caustic soda method, since this furnishes practically no malodorous compounds. The lye and fat are heated together in a clean iron pot or an enamelled pan, the liquids being kept mixed by constant stirring. At the end of a few hours all the solid matters will have dissolved and the fat and lye then form a milky emulsion, from which the former will separate out on standing, and will float, as a clear liquid, on the surface of the lye. When perfectly cold, the purified fat can be taken off from the lye, in the form of a white, inodorous cake. Other fats can be purified in exactly the same manner.

Hog Fat.—Hog fat is the fat of the pig rendered in a similar way to tallow. The finest fat is rendered into lard, the waste and scrapings being separately treated yields an inferior fat suitable for lubricants and for the manufacture of soap. Hog fat produced from old materials may contain a large amount of free fatty acids which would not affect its use for greases but for blending purposes, *i.e.* in cylinder oils this would be highly detrimental. Hog fat is a white, greyish or yellowish fat of a very soft consistency. It has a specific gravity of 0.931 to 0.938 at 15° C., saponification value 195 to 196, iodine value 50 to 70, and melting point 36° to 46° C. Crude hog fat can be refined by treatment with a weak caustic soda solution and then forms an excellent lubricating material.

Bone Fat.—In large towns where considerable quantities of *fresh* bones are always available, the practice of utilising

these in the preparation of lubricants is highly desirable, since they furnish a product almost equal to neatsfoot oil at a very low price. The recovery of fat from the bones does not materially affect their value for the subsequent preparation of glue or bone black.

Fresh bone fat consists of several individual fats, two of which can be readily differentiated, namely, a fat that solidifies somewhat easily, and one that remains liquid even at low temperatures. The latter is the constituent known as bone oil, and is the more important for the production of lubricants.

The author has found the following to be the best method of preparing pure bone fat. The fresh bones are placed in a pan and covered with water, which is then raised to the boiling point very slowly, boiling being continued for several hours and the mass afterwards left to cool. At the end of five or six hours the bone fat will have collected on the surface, and can be skimmed off, into an earthenware vat.

The crude fat from perfectly fresh bones is entirely free from odour; but only small quantities of this grade are obtainable, since, even in large towns, butcher's bones have often suffered deterioration, especially in hot weather, to such an extent that the organic matter is partly decomposed. It is therefore advisable to submit the fat to a refining process, to destroy both the malodorous substances and the yellow-brown colouring matter mixed with the fat.

The best purifying agent is nitro-hydrochloric acid or aqua regia, prepared by shaking up a mixture of 1 part by volume of nitric acid and 4 parts of crude hydrochloric acid in a glass vessel—a metal vessel will not do—until the mixture has assumed a reddish-yellow colour and gives off a penetrating smell resembling chlorine. When these two acids are brought into contact, chlorine is soon liberated; and this substance has a powerfully destructive action on colouring matters and odoriferous substances.

No larger quantity of aqua regia should be prepared than may be needed, since the activity of the reagent is diminished by longer storage.

To bleach the crude bone fat with this reagent it is treated

with 1 to 1½ per cent. of the latter in an earthenware vat, the two being well mixed by prolonged stirring. The quantity of aqua regia required is dependant on the colour and smell of the fat; the darker and more evil smelling the latter, the more of the acid mixture is necessary. The fat and acid are stirred in contact for several hours, to render the chemical reaction as complete as possible.

When the bleaching is completed, warm water is run in and the acid is carefully drawn off through a tap at the bottom of the vat, taking care that no fat escapes along with it. The fat is again mixed with warm water, which is stirred up and drawn off; and this washing is repeated until the last trace of acid has been removed.

Properly bleached fat from fresh bones is nearly colourless and inodorous, free from acid, melts readily, and forms a lubricant closely resembling pure bone oil in quality.

Usually, however, the bones available for making bone fat are very stale, the organic matter being already in an advanced stage of putrefaction, and the fat also more or less decomposed. To use such bones successfully for the preparation of lubricating oils, the method described above must be somewhat modified.

In this case the bones are boiled, as already described, with water, furnishing a strong smelling brown fat, consisting partly of free oleic acid. This fat is ladled into wooden vats, where it is left to stand for several days. As it slowly cools, a granular, greyish-white fat separates out, leaving an evil-smelling brown oil floating on the surface. The solid portion is used for making common soaps, whilst the liquid portion serves for the preparation of lubricants.

This liquid portion is treated with nitro-hydrochloric acid as already described, thereby becoming bleached and purified. The older the bones, the greater the amount of acid necessary to remove the smell and colour of the oil, but the exact quantity can only be determined by direct experiment in each case. Great care should be exercised in using larger quantities than those stated and after the first 1 per cent. of acid is in, any further addition should not exceed ¼ per cent. at a time.

The bleached and deodorised bone fat still contains a large proportion of free oleic acid formed by the decomposition of the fat during the storage of the bones which must be removed before the fat can be used as a lubricant.

This is best effected by treatment with about 10 per cent. of caustic lime, slaked just before use, the resulting milk of lime being stirred up with the fat and left to settle. In this manner the oleic acid is entirely removed by the lime, the neutral fat separating out.

Experiments performed by the author have also shown that the oleic acid can be eliminated by means of litharge, especially when the fat has been previously warmed. The resulting lead oleate remains mixed with the fat, converting it into a mass with the consistency of strong salve, highly suitable for axle grease.

Bone fat is obtained from the bones of any animals, usually those of oxen and sheep. The bones are crushed and digested with water under pressure when the gelatin dissolves and the bone fat rises to the surface from which it is skimmed. It is obtained mostly from glue and animal charcoal factories. Bone fat is also obtained by treating the crushed bones with volatile solvents in special degreasing plants. In this case the bone fat is extracted alone and is easily refined. Bone fat is usually yellowish or yellowish-brown in colour and of a soft consistency; that obtained from fresh bones is quite sweet, but the fat from decomposed bones has a disagreeable odour and a very dark colour. Being obtainable at a comparatively low price, it is well adapted for making cart greases and other low class lubricants; but when refined by treating it with soda and filtering through animal charcoal to eliminate the dark colour and unpleasant smell it may even be used for lubricating fine machinery, clocks, sewing machines, cycles, etc. The specific gravity of bone fat is 0.914 to 0.916 at 15° C., saponification value 191 to 195, iodine value 46 to 56, and melting point 21° to 22° C. The free fatty acids in unpurified bone fat range up to as much as 26 per cent.

Horse Fat is obtained from the fatty portions of the horse being obtained mostly from the "knacker's" yard. It

is a soft white or yellowish fat melting at 20° to 30° C., specific gravity at 15° C. 0.916 to 0.922, saponification value 195 to 197, and iodine value 71 to 86. Horse fat is very similar in its properties to bone fat and may be used for the same purposes; it has, however, a slight tendency to thicken on exposure, although not sufficient to affect its use for the preparation of greases.

Palm Oil is obtained from the fruit of the African oil palm (*Elaeis guineensis*). The general method of preparing the oil as carried on by the natives is to pile up the fruits in a large pit dug in the ground and to allow them to ferment when the oil is expressed by girls stamping it out with their feet. The modern method of extraction is with the hydraulic press, the fruit being comparatively fresh. The oils obtained by these two methods differ very considerably, the fresh oil being much softer than that produced by the native method and containing a much smaller proportion of free fatty acids. Owing to their higher content of glycerine the soft oils fetch a higher price. When fresh, palm oil has the consistency of butter, a bright yellow to orange colour and an agreeable odour; but old palm oil is firmer, friable, darker in colour and has a disagreeable smell.

In the manufacture of lubricants it is highly important to know whether a given sample of palm is fresh or stale; since there is a great difference in the melting points of the two, fresh palm oil melting at 27° C. (80.5° F.) while old or acid oil does not melt below 40° C. (104° F.).

For the majority of lubricants, natural palm oil can be used, which imparts its characteristic yellow colour to the mass. If, however, the colour is undesirable the oil must be bleached.

This operation can be carried out in a simple manner by melting the oil as quickly as possible, then heating it to 240° C. (464° F.) and maintaining it at that temperature for a quarter of an hour. It may also be bleached by treating 1000 parts of the melted fat with 1 to $1\frac{1}{2}$ parts of potassium bichromate and an equal quantity of sulphuric acid. The entire mass turns green at first, a green liquid afterwards settling down and leaving the bleached palm oil floating on the surface.

Palm oil varies in consistency from that of butter to that of tallow; it has a specific gravity of 0.921 to 0.924 at 15° C., saponification value 196 to 205, and iodine value 53 to 57. The free fatty acids are usually high, sometimes extraordinarily high, varying from 7 to 20 per cent. in the soft oils and 60 to 80 per cent. in the hard oils. Palm oil is composed of palmitin and olein with more or less free palmitic and oleic acids.

II. *Liquid Fats or Oils.*—The liquid fats are such as are fluid at the ordinary temperature, though the majority of them set when the temperature is lowered. In many cases the solidification is only partial when the temperature is moderately low, but when great cold is applied, all the liquid fats become solid.

As lubricants, the liquid fats are more particularly suitable for machines that are desired to run at high speeds or that contain delicate parts. Whilst the fats solid at the ordinary temperature are best adapted for greasing waggons, the liquid fats are admirably suited for the preparation of machine oils.

Liquid fats of animal origin are often known as *train oils*, whilst those belonging to the vegetable kingdom are sold under their individual names.

Sperm Oil.—Sperm oil is the oily product obtained from the head cavity and also the body blubber of the sperm whale (*Physeter macrocephalus*). It contains more or less spermaceti, a solid white waxy product which is also sometimes found in the solid state in the head. After extraction, which is done by pressure or by heat, the oil is cooled to a temperature of 32° F. and is kept at that temperature for several days when it forms a semi-solid fat which is pressed in a hydraulic press yielding a fluid oil known as "winter" sperm oil, which remains fluid at that temperature, and a solid fat which is pressed at a higher temperature yielding a small quantity of oil known as "spring sperm oil". The press cakes consist of crude spermaceti which is subsequently purified. Sperm oil is pale yellow to slightly brownish in colour, clear, and with a fishy odour. The specific gravity is 0.880 at 15° C.; saponification value 123.4 to 147.4; iodine

value 70 to 93, the percentage of fatty acids 60 to 64, and the amount of alcohols 39 to 41. Sperm oil is not an oil in the true sense of the word, since it yields practically no glycerine on saponification. It consists of a combination of alcohols and fatty acids the constitution of which is unknown. Sperm oil is one of the best oils for lubricating light machinery and is especially valuable owing to the fact that it shows no tendency to "gum" on exposure.

Whale Oils.—The whale oils or train oils are obtained from many species of whales, the Greenland or Right whale (*Balaena mysticetus*), the Sulphur-bottom whale (*Balaenoptera sibbaldi*), the Humpback whale (*Megaptera longimanus*), the Fin-back whale (*Balaenoptera borealis*), the Bottlenose whale (*Hyperodon rostratum*), and others. The oil is obtained from the blubber by rendering it down with heat.

Whale oil is of a yellow, brown, or reddish brown colour and possesses a strong fishy odour. There are about five grades distinguished in commerce, No. 0 and No. 1, very pale yellow in colour, are usually classed together; No. 2, deep yellow; No. 3, pale brown; No. 4, dark brown. The composition of whale oil is not definitely known, but it contains soluble fatty acids including valeric acid and also clupanodonic acid; it has, however, a similar composition to other fatty oils, being a glyceride and yielding glycerine on saponification. The oil has a specific gravity of 0.920 to 0.925 at 15° C., a saponification value of 188 to 194, and an iodine value of 110 to 146.

Dolphin Oil is obtained from the head and also the body blubber of the dolphin or black fish (*Delphinus globiceps*). The oil is pale yellow in colour and has a strong fishy smell. The oil from the head differs somewhat in composition from that from the body blubber since it contains a considerable amount of volatile fatty acids. The specific gravity of dolphin oil is 0.925 to 0.926 at 15° C.

Porpoise Oil extracted both from the head and also the body blubber of the porpoise (*Delphinus phocaena*), the two oils being different. Both contain volatile fatty acids but the head oil the most. Porpoise oil is pale yellow, brownish-yellow or brown, and has a specific gravity of 0.925 to 0.926.

Train Oil.—Under the names train oil, fish oil, seal oil, etc., a number of oily liquids appear in commerce, ranging in colour through all shades from pale yellow to black, and distinguished by a peculiar, unpleasant smell. In general they are derived from the blubber of certain marine animals, the great bulk being obtained by melting the fat of various kinds of seals and whales. One kind of train oil, cod-liver oil, is obtained from the liver of the codfish.

The train oil brought in enormous quantities every year into European and American ports by whalers is practically the cheapest of all fats. In addition to its use in soapmaking and the production of chamois leather, it is also employed as a lubricant, the chief advantages for this purpose being its oily character and low price.

The cheapest dark and evil-smelling train oil can be used in the preparation of common lubricants, but for finer products it is essential to use the refined oil, which is of a golden yellow colour and has a less penetrating smell.

Neatsfoot Oil is obtained from the feet of cloven-footed animals, oxen, sheep, and goats. It is produced in many small establishments as a by-product in the boiling of "cow-heels" and "sheep's trotters" for food purposes. These are cleansed from blood and dirt by washing them in water, and after the hoofs have been removed they are boiled with water in pans till soft. The fat rises to the top of the liquid on standing and is skimmed off and run into a tank, when, on cooling, it deposits some water and stearin. After a time the clear oil is decanted.

At the large slaughtering yards in America the feet are boiled in large batches in closed boilers under pressure and the oil similarly recovered by skimming off. After it has deposited stearin the clear oil is obtained by putting it through a filter press. Neatsfoot oil is a clear yellowish oil with very little odour and a mild taste. It has a specific gravity of 0.915 to 0.916 at 15° C., saponification value 194 to 199, and iodine value 67 to 76. It consists of olein, palmitin and stearin, the first named predominating. It deposits stearin at a low temperature and solidifies at about -4° C. Neatsfoot oil forms a very useful lubricating oil for fine machinery

as it usually contains but little free fatty acids and keeps well.

Neatsfoot oil occupies a very high place among lubricating oils, being the best for lubricating fine machinery, especially fine machine tools, sewing machines, cycles, small quick-running axles, etc.

It would be equally useful for lubricating larger machines, such as high speed turbines, dynamos, etc., but for the fact that its high price is prohibitive. For makers of high class lubricants, the preparation of neatsfoot oil is strongly recommended; since this oil exhibits a very high state of purity when treated in small quantities, and then forms an unsurpassed lubricant for the finest machinery.

Neatsfoot oil owes its excellent properties to the fact that it may be kept for years in contact with the air without turning rancid or losing its fluidity. This latter property it retains almost unchanged, even at very low temperatures.

The method of producing neatsfoot oil is as follows: The fresh hoofs of oxen, calves, or pigs, after thorough washing, are boiled with water in a pan for a quarter of an hour, the temperature being then reduced so that the liquid is no longer in a state of ebullition. The fat collecting as an oily layer on the surface of the hot water is constantly skimmed off with a flat ladle and transferred to a tall, narrow vessel. The residue in the boiling pan—the hoofs deprived of their fat—may, if fresh, be used as food or otherwise sold to the glue manufacturer.

After standing for some time the neatsfoot oil collects on the surface of the liquid in the vessel in the form of a perfectly clear layer of golden yellow oil. It is then poured off into small white glass bottles, which are tightly corked and exposed to the influence of direct sunlight, which very soon bleaches the oil perfectly white.

A large number of the lubricating oils sold under various names for oiling sewing machines, clocks, and other fine machinery, frequently in very small bottles at a high price, consist simply of neatsfoot oil, prepared, carefully refined, and bleached in the foregoing manner.

It may be mentioned here that to obtain the finest product from neatsfoot oil it should be exposed to a low winter temperature, and, whilst still cold, strained through a fine cloth in order to separate the liquid portion from that which has solidified.

Bone Oil.—On pressing bone fat in a warm room there exudes from it a fluid oil while the residue or stearin left has a higher melting point and therefore is of greater value. The oil contains more olein than the original fat and does not solidify until a lower temperature has been reached. Bone oil forms a useful lubricating material and may be employed for any purpose as it is practically neutral and does not deposit stearin except at very low temperatures.

Lard Oil.—When lard is pressed it also yields a fluid oil known as lard oil and a solid fat called lard stearin. The lard oil varies somewhat according to the composition of the original lard and the temperature at which it has been pressed. Usually it is only semi-fluid at temperatures of 10° to 15°, but if pressed at a low temperature it will form a fluid oil which does not deposit stearin till the temperature is reduced almost to the freezing point of water. The finest lard oil is employed in the preparation of margarine, but second grade oils are employed in the manufacture of lubricants for which they are eminently fitted. Lard oil has a specific gravity of 0.916 at 15° C., saponification value 190 to 193, and iodine value 67 to 88. Some kinds of hog fat are so fluid that they would pass as lard oil.

Tallow Oil is prepared from tallow by pressure at a temperature just below the melting point of the fat. In order to obtain the maximum yield of oil the tallow is heated in a large pan and is kept for a long time just below its melting point, the "stearin" or hard fat crystallises out leaving the olein free. The mass is then made into cakes which while warm are placed in bags and pressed in a hydraulic press, the olein or tallow oil exuding leaving the stearin behind. When fresh beef fat is thus pressed the olein is known as oleo-oil and is used in the preparation of margarine, the solid fat, known as "prime press tallow" or beef stearin, being a useful candle making fat. Tallow oil is a soft fat at the ordinary

temperature and may be used in the manufacture of solid lubricants.

Rapeseed Oil or Colza Oil is obtained from the seeds of *Brassica campestris* and its varieties by pressing. The rape plant is grown in large quantities in most European countries and in India. The seed yields 35 to 45 per cent. of a brown oil which is refined by the acid treatment and then appears of a yellow colour and has a characteristic odour. It deposits stearin on standing at the ordinary temperature. Rape oil has a specific gravity of 0.914 to 0.915 at 15° C., saponification value 168 to 179, and iodine value 93.5 to 105.6. The fresh oil contains but little free fatty acids and forms a very useful lubricating oil, but it has slight drying properties. The solidifying point varies from -10° to +10° C.

According to Lewkowitsch¹ the viscosity may be used as a criterion of the purity of rapeseed oil, since no oil, except castor oil, likely to be used as an adulterant has such a high viscosity. The viscosity of rapeseed oil found by the above author varied from 329 to 380 at 70° F. and 91 to 94 at 140° F.

Mustard Seed Oil is obtained from the seeds of the black mustard (*Sinapis nigra*) and those of the white mustard (*Sinapis alba*) which are cultivated in most parts of Europe, in Asia Minor, India, and North America. The seeds of the black mustard yield about 30 per cent. of a brownish oil, those of white mustard about 25 per cent. of a golden yellow oil. These oils resemble rape oil in their properties, they have a specific gravity of 0.912 to 0.916 at 15° C., saponification value 170 to 178, but the iodine value varies in the two varieties, being 92 to 103 in oil from the white seed and 99 to 122 in that from the black. The solidifying point is about -15° C. Mustard oils have slight drying properties.

Almond Oil is contained in the seeds of the almond, of which there are two kinds, the sweet almond (*Prunus amygdalus*, *Amygdalus communis*) and the bitter almond (*Prunus amygdalus*, var. *amara*), growing in the South of Europe, Morocco, etc. The sweet almond contains 45 to 55 per cent. of oil and that of the bitter almond 35 to 45. The

¹ *Chemical Technology and Analysis of Oils, Fats and Waxes*, 1914, Vol.

characters of the two oils are very similar. Almond oil has a specific gravity of 0.917 to 0.919 at 15° C., saponification value 189 to 195, and iodine value 94 to 101.

Almond oil is a very pale yellow oil with a pleasant odour and taste, it is almost free from fatty acids and keeps for a very long time without becoming rancid. It is composed almost entirely of olein, and having a very low solidifying point, *i.e.* about - 10° C., it forms an exceptionally good lubricating oil.

Earthnut Oil or *Arachis Oil* is extracted from the earth nut (*Arachis hypogaea*) by pressure. The earth nut is grown on a very large scale in India and the West Coast of Africa, in which countries large quantities are consumed as food. The nuts are also imported on a large scale into Europe for extraction of the oil, an industry which has gravitated to Marseilles; the finer kinds of oil are used for food purposes, the commoner qualities for lubricants and soap making. The kernel contains about 45 per cent. of oil. Earth nut oil has usually a pale yellow colour and a pleasant odour. Its specific gravity is 0.916 to 0.917 at 15° C., saponification value 185 to 196, and iodine value 83 to 105. Earth nut oil contains the glycerides of palmitic, hypogaeic, and arachidic acids. It solidifies at about 0° C. and it shows no signs of drying on exposure.

Hazelnut Oil is obtained from the nuts of the hazel tree (*Corylus avellana*), the kernels of which contain about 50 per cent. of a golden yellow oil having an odour of the nut. The specific gravity of the oil is 0.915 to 0.917 at 15° C., saponification value 193 to 197, and iodine value 86 to 90. It is a very fluid oil consisting very largely of olein and solidifying at a temperature of about - 17° C.

Olive Oil.—Olive oil is obtained from the fruit of the olive tree, which is cultivated in Southern Europe, France, Spain, Italy, Greece, etc., also in Morocco, Tunis, Algeria, Palestine, and in South and North America. The pulp of the fruit contains 40 to 60 per cent. of oil. The best oil is obtained from the fresh fruit by pressing; this is neutral, pale yellow or greenish in colour, has a pleasant taste, and is used as a salad oil. A large quantity of the oil is, however, obtained

from fruit which has been allowed to ferment, the oil then having a strong odour and an unpleasant taste. The colour of the oil may be nearly white, green, or yellow.

Olive oil has a specific gravity of 0.915 to 0.918, saponification value 185 to 196, and iodine value 79 to 88. The oil deposits a solid fat at low temperatures and acid oils become quite solid, even at 10° C. The oil is composed largely of olein with a little linolein, but it contains also some palmitin with practically no stearin. The acidity of the better varieties of oil is very low, from 0.25 to 2.5 per cent., but common qualities may contain as much as 25 per cent. of free fatty acids. Olive oil forms a good lubricating oil, but owing to its high price it cannot be largely used except for special purposes, *i.e.* greasing wool for spinning. The commoner oils are unsuitable for use as lubricants owing to their high content of fatty acids, but after refining with alkali these oils can thus be employed and are in great demand.

Castor oil is obtained from the castor bean, the seed of *Ricinus communis*, which is cultivated on a very large scale in India, and also in the West Indies, North America, and Algiers. The seed contains 40 to 50 per cent. of oil. The cold pressed oil, being nearly colourless, is used largely for medicinal purposes; the hot pressed oil is yellowish or greenish and is used for commercial purposes. Castor oil differs in its properties and composition from all other commercial oils. It has the highest specific gravity of any natural oil and the greatest viscosity; it is completely soluble in alcohol and does not mix with mineral oils. These properties are no doubt largely attributable to its composition, it being the glyceride of a hydroxy acid—ricinoleic acid—the formula of which is $C_{17}H_{32} \cdot OH \cdot COOH$.

Castor oil has a specific gravity of 0.959 to 0.968 at 15° C., saponification value 177 to 187, and iodine value 81 to 87. It solidifies at -10° C. The high viscosity of this oil is shown by the experiments of Deering and Redwood, who found the time of flow for 50 c.c. at 100° F. to be 1160 to 1190 seconds.

In a perfectly fresh state, the animal fats are quite inodorous and tasteless substances, which do not react in any

way with either red or blue litmus. They are neutral fats, *i.e.* they contain no trace of free fatty acid. A similar behaviour is exhibited by certain vegetable oils, such as freshly pressed olive oil, rape oil, and a large number of other oils.

When the perfectly fresh fat is packed into a cask in such a manner that the admission of air is rendered quite impossible, the fat will remain in an unaltered condition, as neutral fat, for a considerable time. If, however, the fat be exposed to the action of the air, a peculiar chemical change, known as rancidity, soon becomes perceptible.

Rancid fat is no longer neutral, but acid in its action, which condition is revealed by its turning blue litmus red. The fat now contains a larger or smaller quantity of free fatty acids, the presence of which is made manifest by a certain peculiar smell and a sharp, irritating taste.

When brought into contact with metals like copper, iron, or bronze, perfectly neutral fat leaves them quite unaltered, whereas fat that has become acid, *i.e.* rancid, acts very energetically on metals, and soon corrodes them. This can sometimes be clearly seen on machine parts made of copper, bronze, or brass, the lubricant running down these parts being stained green by dissolved copper.

In large machines this action of fats on the several parts is not a great disadvantage, nor can it be easily prevented. It is, however, different with lubricants intended for use in delicately constructed mechanisms, such as clocks, sewing machines, and others of similar character.

For such machines the only permissible lubricants are those that are entirely destitute of free acid, and are therefore without any corrosive action on the metal.

The vegetable oils used as lubricants should also be examined for their behaviour on exposure to the air. True, all oils will turn rancid sooner or later, but in many of them a very remarkable alteration of consistency also occurs.

Certain oils, *e.g.* rape oil and olive oil, will become very acid and somewhat thicker after a certain time, but they always remain perfectly fluid, even though kept exposed to the air for years. Other oils—which are typified by linseed

oil and nut oil—have the property of becoming progressively thicker when left to stand in the air for some time, and are finally converted into solid, resinous masses.

Oils exhibiting this latter peculiarity are termed drying oils, in contradistinction to the non-drying oils. This property of the drying oils to gradually change into solid bodies renders them unsuitable as lubricants, for when a machine that has been lubricated with such oils is left unused for some time, the oil dries on the various parts of the machine, forming a coating that is very difficult to remove. Hence the specifications for the supply of large quantities of lubricating oils often contain a clause prohibiting the use of drying oils as ingredients.

The volatile oils obtained in refining petroleum and tar are not liable to become rancid; hence, viewed from the standpoint of chemical inactivity, these oils are preferable to the fats and vegetable oils. On the other hand, some of these mineral oils thicken in course of time—though much more slowly than the vegetable oils—without, however, turning acid (rancid). They undergo conversion into resinous products by polymerisation, in which event they are said to “resinify” or “gun”.

TREATED OILS.

Polymerised Oils.—On heating castor oil to 260° to 300° C. for several hours it becomes polymerised and is then soluble in petroleum oils. Use is made of this fact for the preparation of mixed lubricants containing both castor oil and mineral oil.

Polymerisation may be brought about by heating the oil to about 300° C.,¹ by heating for 10 hours to a temperature of 260° to 300° C. under pressure or at ordinary pressure under a reflux condenser,² also by heating the oil with formaldehyde to a temperature of 500° C.³

H. Boyer, L. Cavillon, and N. Barishac treat the oil by heating it with the acid anhydrides or chlorides of mineral

¹ Nordlinger (Ger. Pat. 101,499).

² Oelwerke Stern-Sonneborn, Akt.-Ges., Hamburg, Eng. Pats. 24,985 and 24,986, Dec. 1, 1905.

³ Common and Hull Oil Manufacturing Co., Eng. Pat. 15,466, 1908.

acids, for instance 4 per cent. of acetic acid, the product being mixable with mineral oils.¹

Blowing.—When castor oil is heated to a temperature of 70 to 110° C. it gradually thickens, becomes much more viscous, and has a higher specific gravity. In this reaction the unsaturated acids become oxidised with consequent lowering of the iodine value, a certain amount of the oil is decomposed, and volatile fatty acids are formed, some of which are evolved.

The change which takes place may be followed by a comparison of the analytical figures for the original oil and for the oil blown for different periods of time. The following are the results obtained by Lewkowitsch² for castor oil:—

	Original Oil.	Blown at 150° C.			
		2 Hours.	4 Hours.	6 Hours.	10 Hours.
Color	Very light.	Light.	Light.	Light.	Orange-yellow.
Specific gravity at 60° F.	0.9623	0.9663	0.9798	0.9778	0.9906
Acid value	1.1	1.3	2.4	2.6	5.7
Saponification value	179.0	182.3	185.2	184.8	190.6
Iodine value	—	83.5	79.63	78.13	70.01
Acetic value	146.0	150.7	154.3	159.0	164.8
Saponification value of acetylated oil	804.3	806.0	808.7	—	—

Procter and Holmes³ have also examined the products obtained by blowing many oils including an English expressed castor oil, their results being as follows:—

Blown	Specific Gravity.	Refractive Index.	Iodine Value.
Hours.			
0	0.958	1.4800	83.0
3	0.958	1.4800	83.0
6	0.958	1.4802	74.0
9	0.958	1.4804	73.0
12	0.961	1.4804	72.0
15	0.962	1.4805	71.0
18	0.965	1.4805	71.0
21	0.966	1.4806	69.0
24	0.967	1.4807	68.0

¹ Eng. Pat. 15,457, 1909.

² *Chemical Technology and Analysis of Oils, Fats, and Waxes*, 1914, Vol. II., p. 339.

³ *Jour. Soc. Chem. Ind.*, 1905, 1289.

Semi-drying oils such as cottonseed oil and fish oil, are also altered more or less, by blowing as shown by the following results:—

	Specific Gravity	Viscosity at 100°C.	Flash Point	Ignition Point	Remarks
	15°C.	100°C.	Value	Value	Value
Blown rape	0.9372	4.6	167.5	62.6	84.7 Thomson and Ballantyne
"	0.93714	—	205.6	—	—
Original "	0.9333	2.2	170	66.2	—
Blown "	0.9372	3.5	164	57.2	—
"	0.93745	4.1	172.1	54.1	—
"	0.9375	4.2	177.5	61.3	—
" Rape-seed	0.9385	5.28	168.4	52.6	—
Blown East India rape	0.9372	6.62	215.57	61.62	—
Blown cotton-seed	0.9375	4.70	214.59	65.74	—
"	0.9372	—	213.7	—	—
"	0.93740	3.28	213.2	56.4	—
" maize	0.9386	3.66	208.63	60.7	—
" seal	0.9385	16.5	221.0	78.2	—
" sperm	0.9389	3.27	142.3	67.1	—

For further particulars of these oils see the references given in the footnotes.

Owing to their high viscosities the blown oils are often used in compounding lubricating oils. Whether they are altogether suited for this purpose is a debatable question. They are not entirely free from a tendency to "gum," while their acidity and low flash points are also factors which have to be taken into account.

According to S. Hilpert,¹ blown whale oil forms an exceptionally good thickening agent for tar oils, the flash point of the product being comparatively low.

¹ *Jour. Soc. Chem. Ind.*, 1912, 2nd.

² *Oils, Fats and Waxes*, Vol. III., pp. 16-177.

³ *Bull. de l'Assoc. Belge de Chim.*, 1901, 325.

⁴ *Jour. Soc. Chem. Ind.*, 1899, 342.

⁵ *Chem. News*, 1894, 2.

⁶ *Ges. Abhandl. Zur Kenntnis der Kohl.*, 1917, 1, 266-269. *Chem. Soc. Trans.*, 1919, 528A.

Sulphonated Oils.—When concentrated sulphuric acid is allowed to act upon oils, the temperature being kept low by cooling, hydroxy fatty acids and their sulphuric esters are formed, but in the case of castor oil free ricinoleic acid and ricinoleo-sulphuric acid with mono- and di-ricinoleic acid and probably other products are produced. These products are used in Turkey red dyeing, for which reason they are often known as Turkey red oils. The product from castor oil is also known as "soluble oil". The method of preparing soluble oil is to run concentrated sulphuric acid into castor, which is kept at a temperature below 35° C. by cooling. A little water is then added to the oil, agitated with it, and then allowed to settle out, after which the oil is syphoned off. The oil is washed with a solution of Glauber salts until practically all the acid has been washed out. Ammonia or soda is then added to the oil until it forms a clear solution when mixed with a little water. This forms the soluble oil of commerce. On adding to water it yields a clear or milky solution, and a mixture of it with other oils will also give emulsions. Soluble oil will mix with all other fatty oils but not with mineral oils. It can, however, be mixed with the latter by using oleic acid and ammonia, such mixtures forming very permanent emulsions with water. These latter, known as "screwing" and "cutting" oils, will be described in a later chapter.

L. Hirschberg (Assignor to Chemische Fabrik, Westend, U.S. Pat. 1,042,915) claimed that by heating hydrocarbon oils with an equal weight of sulphuric acid, containing sulphur trioxide equivalent to at least 2½ per cent. of the weight of the oil, to a temperature of 100° to 180° C. the mass separates on cooling into two layers, the upper layer after separation and neutralisation being emulsifiable with water.

CHAPTER III.

SUBSTANCES USED IN THE PREPARATION OF LUBRICANTS (continued).

HYDROCARBON OILS, ETC.

Petroleum Oils.—The discovery of a petroleum oil in a coal pit at Alfreton in Derbyshire and the working of it by Young in or about 1847, which led to great developments in the shale oil industry, are adverted to in another chapter. Natural petroleum exuding from the earth's surface or found in wells had long been known in North America, the material being used for medicinal purposes under the name of "rock oil".

The first petroleum well was sunk in 1858-59 by Col. G. L. Drake at Titusville, in the State of Pennsylvania, and a company was formed by Messrs. Eveleth and Bissell, under the name of the Pennsylvania Rock Oil Company, to work it. The total production in 1859 amounted to somewhat less than 2000 barrels. Wells were afterwards sunk in the valley of the Muskegon, Ohio, at Lima, Findlay, and Bowling Green, in West Virginia at Burning Springs, which was a most productive well, in the Bradford field and at Cherry Grove, the latter being long famous as a flowing well, at Hughes River and at Oil Springs. Wells were also sunk in South California at Ventura, Los Angeles and Santa Barbara, and in Kentucky, Tennessee, Illinois, Kansas, and Texas, all of which are oil-producing states. It is from the deposits in the United States that by far the larger bulk of the world's petroleum supplies are obtained, and the immensity of the trade is clearly shown by the statistics below :—

Production of Crude Petroleum in the United States.

	1901.	1911.	1913.	1914.	1915.
Metric tons .	8,951,000	29,393,252	46,956,337	50,229,119	37,480,547

United States Exports.

		U.S. Gallons.	
	1914.	1915.	1916.
Crude oil	146,056,086	154,703,618	168,358,167
Naphtha	185,578,776	273,806,978	349,721,727
Illuminating oil	1,155,809,430	885,246,438	852,765,091
Lubricating oil and paraffin	195,472,181	237,660,120	258,993,634
Residuum, gas and fuel oils	586,218,073	808,343,638	953,199,203
Total	2,269,134,546	2,309,760,792	2,583,037,822
Total values	—	\$141,004,663	\$199,630,471

In 1905 the percentage yield was: Burning oil 61, paraffin oils 2·9, reduced oils 7·7, naphtha and gasoline 10·3, neutral filtered oils 0·9, paraffin wax 1·4, residuum 5·7.

The origin of petroleum is a much discussed problem, Prof. Engler, of Carlsruhe, being of opinion that it has been formed by the slow distillation of animal and vegetable matter by the internal heat of the globe. That it was formed in the primary rocks as at first supposed is now known not to be the case, as it may have been formed in any strata and has percolated down into large fissures. It sometimes oozes to the surface, but is found at various depths and often accompanied by brine.

In the United States the wells are sunk to a great depth, *i.e.* 2300 to 2500 feet. The American method of boring is now almost universally employed. First, a derrick is built on which revolves a wheel carrying cams which lift the cable and boring tool. These derricks are a familiar feature of the landscape in oil-bearing districts. At the side of the derrick is built a shed for the boiler and engine. The boring tools of chilled steel are alternately lifted and allowed to fall and are also rotated in the hole, the cable being payed out and held by a clip as the tool descends; the hole is also flushed out with water from time to time to remove the debris of rock formed by the tool. When a sufficient depth has been reached with but little oil appearing a charge of dynamite is exploded in the boring, which shatters the rock and often leads to a great rush of oil, a "gusher" as it is called,

which may play like a high fountain into the air for a long period, the oil blowing in spray all over the country, much of it being lost. Sometimes the fountain catches fire, a most imposing sight, and an enormous dense column of smoke surmounts the fountain. Natural gas usually accompanies the oil, which is burnt under the boiler. After a time the flow of oil subsides and resort is then made to pumping, the well being sheathed with wrought iron tubes and a pump installed. The refineries for Pennsylvania oil are on the east coast near the large ports—Philadelphia, Baltimore, New York and Boston, the refinery at Philadelphia being one of the largest in the world. Ohio oil is refined in the cities on the great lakes, principally at Cleveland and Chicago, the refinery at Whittings on the shores of Lake Michigan in Indiana being probably the largest refinery in the world.

The oil from the wells is carried through pipe lines, hundreds of miles, to the refineries. In the United States the refineries are on a gigantic scale, there being sometimes hundreds of boilers or stills, with their accompanying condensers, refrigerating plant and storage vessels, etc. By distillation the crude oil is separated into several fractions, naphtha, kerosene, lubricating oils, and residuum, etc., all of which find a use for a variety of purposes. The crude petroleum flows in a constant stream into the refinery and by the aid of pumps is caused to circulate through the stills, condensers, and refining tanks until finally it passes to the huge storage tanks from which it is delivered into tank waggons or barrels for consumption. The Ohio oil contains a high proportion of sulphur compounds which originally caused a considerable amount of trouble, but it is now freed from sulphur by the method of Hermann Frasch, which consists in passing the vapours of the oil over finely divided copper oxide.

In Canada there are deposits of oil in the Ontario district at Athabasca Lake and on the Great Mackenzie River. A considerable quantity of oil is also obtained in Mexico, Peru and Argentina in South America, while there is also a large amount accompanying the bitumen in the bitumen lake of

Trinidad. The production of crude oil in barrels in Mexico in 1901 was 9750, and in 1914, 31,867,410 U.S. gallons (and that of Trinidad in 1917 upwards of 4,500,000 gallons). In Europe petroleum is found in Alsace, Italy, Roumania, Galicia and Russia. The Russian oil fields, which are by far the largest European deposits, occur mostly in the Caucasus or Caspian Sea area.

Oil has been known to occur at Baku from very early times. This district belonged to Persia and the Parsees who inhabited it were fire-worshippers, regarding as holy the fires which were produced by burning the oil as it oozed from the ground, and which they kept alight for many centuries. In 1806 Baku passed into the hands of Russia, and many oil wells were sunk, chiefly in the Balachany and Sabountchi fields at Bibi Eibat and on the Maikop field. The oil is found at moderate depths, the oil wells usually being 190 to 200 metres deep.

Petroleum is also often found on the waters of the Caspian Sea, and gases are evolved which sometimes take fire and burn for a time.

The oil is refined in Baku in the district known as the "black town," with which the Balachany field is connected by pipe line. The stills are heated by the residue or "masut" which is blown into the fire holes over which they are fixed. The greater part of the Russian oil supplies comes from Baku. In 1913 the production of crude oil was over 9,000,000 tons and in 1914 it exceeded 8,900,000 tons, the proportion of the different products in the years 1906 and 1907 being as follows:—

	Poods of 36·112 lb.	
	1906.	1907.
Crude naphtha	33,331,587	35,317,006
Petroleum and distillates	72,050,819	86,211,416
Lubricating oils	13,123,825	12,541,628
Oil residues	1,030,678	1,376,936
Lubricating masut }	203,749,605	234,786,946
Residuum " }		
Viscosin, paraffin wax, etc.	28,967	40,971

In Galicia the oil wells are in the districts of Bobrka and Sloboda-Rungwiska. There is also petroleum accompanying ozokerite at Boryslaw which is the centre of the ozokerite industry. The wells in this country were

originally very shallow, merely a few feet deep, and in large numbers; the oil which oozed into them from the surrounding strata being drawn to the upper surface by very primitive windlass and bucket devices. Now, however, the American system has been introduced, the wells are deeper and the oil is pumped out.

The total production of crude oil in Galicia was as follows:—

	Metric Tons.
1907	1,175,974
1908	1,784,235
1909	2,150,000

and the exports in 1910:—

Petroleum spirit	32,528
Crude oil	51,558
Refined oils	290,915
Lubricating oils	100,716
Gas oil	25,630
	<u>504,353</u>

In Roumania the production was as follows:—

	Metric Tons.
1913	1,885,225
1914	1,738,947
1915	1,678,145

and the exports:—

	1913.	1914.
Benzine	237,168	164,143
Lighting oil and distillates	418,622	297,900
Crude oil	28,622	15,405
Mineral oil	9,543	5,617
Residues and gas oil	341,912	167,523
Paraffin	579	536
Total	<u>1,036,446</u>	<u>654,024</u>

In Asia petroleum is found in India in Rangoon, Upper Burma region and in Upper Assam, also in Japan, in Borneo, Ceylon, and also in Mesopotamia. Burma exports about 800,000 gallons of benzine annually. The Japanese production of crude oil was as follows:—

	American Gallons =0·8·3 Imperial Gallons.
1914	115,849,104
1915	127,367,523
1916	127,056,624
1917	121,790,640

Imports of Petroleum Products into the United Kingdom in 1914.
Gallons.

Country.	Benzine.	Illuminating Oil.	Lubricating Oil.	Gas Oil Solar.	Fuel Oil.	Residuals.	Other Descriptions.	Total.
Belgium	32,280	—	538,100	—	—	2,000	1,350	578,680
Canada	—	—	21,300	—	—	88,510	—	109,810
Dutch Indies	52,125,000	90	—	—	83,800	—	1,750,240	53,958,180
Germany	—	29,250	1,471,500	—	—	—	7,480	1,508,190
Holland	5,063,480	—	12,230	182,000	280	—	13,690	5,271,630
Mexico	2,434,380	12,364,790	256,800	—	15,031,040	—	995,010	31,082,020
Roumania	6,412,450	13,033,080	—	—	2,348,570	961,440	—	22,755,570
Russia	10,202,000	4,574,390	6,454,430	—	—	5,400	630	21,237,500
U.S.A.	40,766,060	116,595,460	54,846,900	83,470,250	18,748,300	2,570,740	735,410	317,705,710
Other countries	3,423,970	4,170	260,810	1,460	8,900	—	1,843,230	5,542,500
Totals	120,460,150	146,601,230	63,862,120	83,653,710	36,210,890	3,628,090	5,346,990	459,744,740

In Japan the refineries are mostly at Echigo, which turned out in the years 1911 and 1912 the following products :—

	Barrels of 42 Gallons.	
	1911.	1912.
Benzine	208,916	333,818
Kerosene	21,523,434	21,674,660
Neutral oil	7,921,401	6,494,591
Lubricating oil	7,591,105	7,409,606
Fuel oils	30,051,498	26,771,382

Boring for oil was carried out in several places in England during the war but with very little success. The most productive well was that at Hardstoft, in Derbyshire, from which 260 gallons per day were obtained.

The table on page 58 from the *Petroleum Review*, 1915, shows the import of various petroleum products into the United Kingdom in 1914 and the sources.

The extent of the petroleum industry will be seen from the following figures for the world's production :—

	Metric Tons.				
	1901.	1911.	1913.	1914.	1915.
U.S.A.	8,954,000	29,393,252	46,956,337	50,229,119	37,480,547
Russia	10,984,000	9,066,259	11,875,693	12,666,879	9,353,077
Mexico	—	1,873,552	4,895,561	4,004,613	4,388,068
Sumatra, Java, Borneo	613,000	1,670,668	2,261,736	2,401,285	1,710,445
Roumania	225,000	1,544,072	2,561,851	2,424,224	1,673,145
India	—	897,184	1,498,798	1,512,000	966,667
Galicia	451,000	1,458,275	1,477,626	951,303	578,788
Japan	—	221,187	367,040	517,553	415,785
Peru and South America	—	186,405	403,176	362,464	331,633
Germany	—	140,000	188,200	188,200	140,000
			(estimated)	(estimated)	
Trinidad	—	—	95,183	121,628	100,000
Argentina	—	—	—	59,400	75,900
Egypt	—	—	19,823	163,178	29,569
Canada	—	38,813	43,107	40,598	28,729
Italy	—	10,000	8,932	7,174	5,500
					(estimated)
All other countries	484,000	26,667	51,030	3,780	1,333
Totals	21,709,000	46,526,325	72,704,093	75,653,698	57,298,786

The crude petroleum is a black, brownish-black, brown,

amber coloured, or yellow liquid, fluorescent, having a specific gravity varying between 0.771 and 0.976. It has a flash point (Abel test) from 24° to 320° F. and a solidifying point varying from 80° to zero.

The composition of crude petroleum varies very considerably in different localities, and in fact in different wells in the same field. American petroleum consists chiefly of paraffins but contains some olefines and naphthenes. The Caucasian petroleum is composed principally of naphthenes. Benzene and its homologues have been discovered in small quantities in most petroleum.

The following have been detected in Pennsylvanian petroleum:—¹

Paraffins of the Series.		C_nH_{2n+2}	Boiling Point, °C.	Specific Gravity.
Gaseous.	Methane . . .	CH_4	—	—
	Ethane . . .	C_2H_6	—	—
	Propane . . .	C_3H_8	—	—
	Butane . . .	C_4H_{10}	0	—
Liquid.	Pentane (normal)	C_5H_{12}	38	0.628
	Pentane (iso)	C_5H_{12}	30	0.628
	Hexane (normal)	C_6H_{14}	69	0.664
	Hexane (iso)	C_6H_{14}	61	0.664
	Heptane (normal)	C_7H_{16}	97.5	0.699
	Heptane (iso)	C_7H_{16}	91	0.699
	Octane (normal)	C_8H_{18}	125	0.703
	Octane (iso)	C_8H_{18}	118	0.703
	Nonane . . .	C_9H_{20}	136	0.741
	Decane . . .	$C_{10}H_{22}$	158	0.757
	Endecane . . .	$C_{11}H_{24}$	182	0.765
	Dodecane . . .	$C_{12}H_{26}$	198	0.776
	Tridecane . . .	$C_{13}H_{28}$	216	0.792
	Tetradecane . . .	$C_{14}H_{30}$	238	—
	Pentadecane . . .	$C_{15}H_{32}$	258	—
	Hexadecane . . .	$C_{16}H_{34}$	280	—
	Octodecane . . .	$C_{18}H_{38}$	—	—
	? . . .	$C_{20}H_{42}$	—	—
	? . . .	$C_{22}H_{46}$	—	—
	? . . .	$C_{24}H_{50}$	—	—
Solid.	Paraffin (myricyl)	$C_{27}H_{56}$	—	—
	Paraffin (ceryl)	$C_{30}H_{62}$	370	—

According to Höfer the following olefines have been separated from North American petroleum:—

¹ Sir Boverton Redwood, *Petroleum*, 1896, Vol. I., 207.

Olefines of the Series C_nH_{2n} .

		Melting Point. °C.	Boiling Point. °C.
Ethylene	C_2H_4	- 160	- 103
Propylene	C_3H_6	—	Gas
Butylene	C_4H_8	—	- 5
Amylene	C_5H_{10}	—	35
Hexylene	C_6H_{12}	—	69
Heptylene	C_7H_{14}	—	98
Octylene	C_8H_{16}	—	124
Nonylene	C_9H_{18}	—	153
Decatylene	$C_{10}H_{20}$	—	172
Endecatylene	$C_{11}H_{22}$	—	195
Dodecatylene	$C_{12}H_{24}$	- 31	96 at 15 mm. press.
Decatrilene	$C_{13}H_{26}$	—	233
Cetene	$C_{16}H_{32}$	+ 4	274
Cerotene	$C_{27}H_{54}$	58	—
Melene	$C_{30}H_{60}$	62	—

Hydrocarbons of the Benzene Series, C_nH_{2n-6} .

Small quantities of the following have been found in petroleum.

		Melting Point.	Boiling Point.
Benzene	C_6H_6	6	79
Toluene	C_7H_8	below - 28	110
Xylene (iso)	C_8H_{10}	—	119
Xylene (para)	C_8H_{10}	13	137
Cumene	C_9H_{12}	—	153
Cumene (pseudo)	C_9H_{12}	—	169
Mesitylene	C_9H_{12}	—	163

The naphthenes which occur in Caucasian petroleum are derivatives of benzene, and although they have the same constitutional formulæ as the olefines they have quite different properties. It is usual to refer to them as methylenes or naphthenes, and names are also applied which show their relationship to the benzene series, thus hexamethylene, C_6H_{12} , is hexahydrobenzene (Kishner), and Heptamethylene, C_7H_{14} , may be termed hexahydrotoluene (Lossen).

The following (page 62) have been isolated.

The crude petroleum is distilled in large boilers and yields

a volatile oil known as naphtha or benzene, or more recently as petrol, burning oil or kerosene, lubricating oils, and a residual product which varies according to the length of the

		Boiling Point.	Specific Gravity.
Hexamethylene . . .	C_6H_{12}	69°	0.7539
Heptamethylene . . .	C_7H_{14}	97°	0.772
Octomethylene . . .	C_8H_{16}	115°-124°	0.777-0.7835
Nonomethylene . . .	C_9H_{18}	135°-142°	0.7808-0.7812
Decamethylene . . .	$C_{10}H_{20}$	153°-170°	0.7808-0.814
Endecamethylene . . .	$C_{11}H_{22}$	179°-181°	0.8019 at $\frac{16.2^\circ}{40^\circ}$
Dodecamethylene . . .	$C_{12}H_{24}$	197°	0.812 at $\frac{18.4^\circ}{40^\circ}$
Tetradecamethylene . . .	$C_{14}H_{28}$	240°-241°	0.8125 at $\frac{18.6^\circ}{40^\circ}$
Pentadecamethylene . . .	$C_{15}H_{30}$	246°-248°	0.821 at $\frac{18.8^\circ}{40^\circ}$

distillation. In some cases the distillation is stopped when all the lighter oils and much of the heavier or lubricating oil has passed over leaving a heavy, extremely viscous product

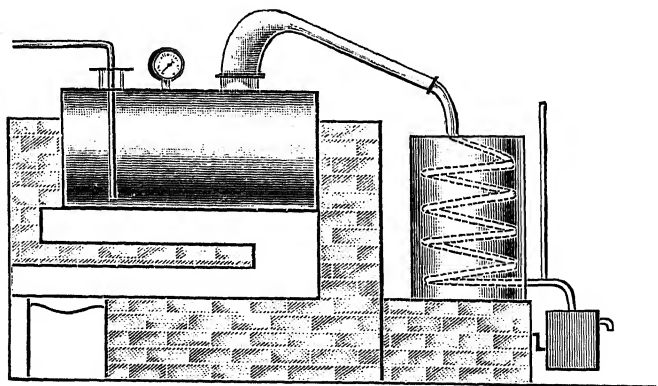


FIG. 9.—Still for crude petroleum.

which is cooled by refrigeration, the solid paraffin being separated by filtration, and subsequently purified; the residue, having great body and high flash point, is sold as a cylinder

lubricating oil. In other cases the residue is run into a coking still and distillation continued until the product left resembles pitch or asphalt or is even converted into a kind of coke. During the distillation the products passing over are diverted into different receivers as the temperature rises and the specific gravity of the distillate increases.

The products of the first distillation require to be refined, which is done in large tanks, treating the oil with 1 or 2 per cent. of sulphuric acid, separating the black tarry mass which deposits, and then treating the oil with caustic soda and washing with water. After this refining the products are again distilled in separate stills, which vary in construction, but are essentially similar to Fig. 9.

Crude petroleums vary very considerably in composition, therefore the nature of the products and the yield are also variable as will be seen from the following figures (page 64).

In the second distillation the oils may be further separated by fractionation into a number of products. In the United States the following have been recognised :—

	Boiling Point.	Specific Gravity.	Application.
Cymogene . .	32° F.	0.529-0.603	Artificial freezing.
Rhigolene . .	65° F.	0.603-0.629	Anæsthetic.
Gasolene . .	—	0.629-0.673	Air-gas lamps.
Naphtha . .	—	0.623-0.673	Cleaning, etc.
Benzine . .	—	0.723-0.744	Paints and varnishes.
Kerosene . .	—	0.744-0.838	Lamp oil.
Paraffin oil . .	—	0.838-0.906	Separated into lubricating oil and paraffin wax.

The following is a list of products from Russian petroleum drawn up by the Baku section of the Russian Technical Society which has been accepted by the Russian Excise Authorities :—

A. *Crude Oil*: The natural product unrefined. If the flash point (open test) be above 70° C. the product is classified under residuals Group E.

Fractional Distillation of Mineral Oil from Various Sources.

Origin.	Colour.	Con- sistency.	Den- sity.	Spirit.		Light Oil.		Lubricating Oil.		Paraffin Oil.		Paraffin.		Residuum.		Asphaltum.		Coke.		Gas.		Loss.		Analyst.
				Den- sity.	Per Cent.	Den- sity.	Per Cent.	Den- sity.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
Egyptian .	Brown black	Viscous	0.958	—	—	—	26.7	—	61.2	—	—	—	—	—	—	—	—	7.7	—	4.3	—	—	F. Weyl.	
African .	—	—	0.912	—	—	—	0.835	80.3	0.887	59.5	—	—	—	—	—	—	—	—	—	—	—	—	N. Tate.	
Canadian I.	Brown black	Viscous	0.828-	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
II.	—	—	0.878	0.785	12.5	—	0.820	35.8	—	43.7	—	3.0	—	—	—	—	—	8.2	—	—	—	—	Muspratt.	
III.	—	—	0.843	0.720	14.5	—	0.815	36.3	0.882	39.4	—	4.34	—	—	—	—	—	2.9	—	1.1	—	—		
Ennistillen I.	—	—	0.845	0.794	20.0	—	0.837	50	—	—	22	—	—	1	—	—	—	2	—	—	—	—		
II.	—	—	0.840	—	—	—	—	56	—	43	—	3	—	—	—	—	—	—	—	—	—	—	Gintl.	
Pennsylvanian I.	Dark greenish	Viscous	0.813	—	15.5	—	—	55.5	—	17.5	—	2	—	—	—	—	—	—	—	—	—	—		
II.	brown	—	0.862	0.735	14.7	—	0.820	41	—	39.4	—	2	—	—	—	—	—	2.1	—	—	—	—	Chandler.	
III.	—	—	0.800	—	—	—	—	41	—	39	—	2	—	—	—	—	—	—	—	—	—	—		
IV.	—	—	0.795	0.720	18.2	—	0.820	32.45	0.850	36.5	—	2.85	—	—	—	—	—	3.4	—	—	—	—	N. Tate.	
Oil Creek .	—	—	0.800	0.756	17.5	—	0.824	39	—	41	—	2	—	—	—	—	—	0.5	—	—	—	—		Gintl.
Californian I.	Almost black	Viscous	0.816	0.715-	23.0	—	0.810	56.3	—	11	—	0.5	—	—	—	—	—	4.8	—	—	—	—	Ott. —	
II.	—	—	0.826	0.745	22.8	—	0.820	50.1	0.870	18.3	—	0.6	—	—	—	—	—	2.6	—	—	—	—		A. Berndt.
Argentina .	Almost black	—	—	0.740	6	—	0.814	29	0.900	53	—	—	—	—	—	—	—	10	—	2	—	—	L. Baker.	
Caucasian I.	From pale to	Limpid	0.783	0.720	4.5	—	63.3	—	29.3	—	—	—	—	—	—	—	—	—	—	—	—	—		Albrecht.
II.	black	to viscous	0.775	—	7.8	—	81.3	—	9	—	—	—	—	—	—	—	—	—	—	—	—	—	Merz.	
Surakhani I.	White naphtha	—	0.770	—	10.6	—	—	82.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—		10
Balakhan I.	—	—	0.905	0.760	4.55	—	0.820	28.4	0.880-	41.7	—	—	—	—	—	—	—	—	—	—	—	—	15.35	
II.	—	—	0.910	0.760	3.90	—	0.820	23.4	0.905	—	—	—	—	—	—	—	—	—	—	—	—	—		9.15
Baku .	Dark	Limpid	0.836	—	—	—	0.812	26	0.905-	43.5	—	—	—	—	—	—	—	—	—	—	—	—	—	
Wallachia	—	—	0.843	0.705	9.75	—	0.780	56.4	0.920	3.2	—	—	—	—	—	—	—	—	—	—	—	—	9.15	
Moldavia .	—	—	0.550	—	14.2	—	45.6	—	0.890	18.35	—	2.25	—	—	—	—	—	—	—	—	—	—		—
												3	—	—	—	—	—	—	—	—	—	—	—	

	Specific Gravity.	Naphtha.	Illuminating Oil.	Lubricating Oil.	Paraffin.	Asphalt.	Loss.
Rangoon (M. Vohl)	0.885	—	4.01	40.999	6.071	41.3	7.62 <i>Water.</i> 4
California (J. H. White)	0.927	—	38	48	—	10	—
Pennsylvania (Norman Tate)	0.815	15.2	39.5	38.4	3.0	<i>Coke.</i> 2.7	1.2
" " "	0.820	4.3	44.2	45.7	2.7	2.2	0.9
Canada (Ontario) (Imperial Institute)	—	12.5	35.8	43.7	3.0	<i>Waste.</i> 5.0	—
" " "	—	1.6	38.7	25.3	—	34.4	—
New Brunswick	—	5.6	28.3	53.2	—	<i>Water.</i> 7.9	—
Trinidad (Imperial Institute)	0.920 at 20° C.	11.1	38.0	43.0	—	<i>Coke.</i> 7.9	—
" " "	—	—	25.0	43.6	—	<i>Bitumen.</i> 17.0	—
" " "	0.8686 at 20° C.	0.2	70.0	27.4	—	<i>Coke.</i> 2.4	—
Boryslaw 24 samples (M. Wielezyski)	0.8968-0.9634 at 17.5° C.	5.2-19.0	37.51	—	0.53-13.8	—	—

B. Light Products :—

1. Petroleum ether, rigolene, sherwood oil ; specific gravity not exceeding 0·700 and distilling completely up to 80° C.
2. Light benzine ; specific gravity 0·700 to 0·717 ; not more than 5 per cent. left on distillation at 100° C.
3. Heavy benzine ; specific gravity 0·717 to 0·730 ; not more than 5 per cent. left on distillation above 100° C.
4. Ligroin, specific gravity 0·730 to 0·750.
5. "Putz" oil (cleansing oil) ; specific gravity 0·750 to 0·770.

C. Illuminating Oils :—

1. Meteor, specific gravity 0·806 to 0·810 ; flashing point (Abel-Pensky) not below 28° C. ; colour 1 to 2 "marks".
2. Testefas, specific gravity 0·820 to 0·823 ; flashing point not below 38° C. ; colour 1 to 2 "marks".
3. Kerosene, specific gravity 0·815 to 0·826 ; flashing point not below 28° C. ; colour 2½ "marks".
4. Astralene, specific gravity 0·832 to 0·835 ; flashing point 40° to 45° C. ; colour 2½ "marks".
5. Pyronaphtha, specific gravity 0·855 to 0·865 ; flashing point not below 98° C. (Martens-Pensky) ; colour, discoloured.
6. Gas oil, specific gravity 0·865 to 0·885 ; flashing point not below 93° C.
7. Light solar oil, specific gravity 0·878 to 0·885 ; flashing point 125° C.

D. Lubricating Oils :—

1. Lubricating oil, specific gravity 0·885 to 0·895 ; flashing point 135° to 185° C. ; viscosity (Engler) at 50° C. 2 minutes 4 seconds to 2 minutes 9 seconds.
2. Spindle oil, specific gravity 0·895 to 0·900 ; flashing point 150° C.
3. Machine oil, specific gravity 0·905 to 0·911 ; flashing point 185° to 215° C. ; viscosity 6 to 7·5 minutes ; freezing point - 10° C.

4. Cylinder oil, specific gravity 0·911 to 0·920; flashing point 210° to 245° C.; viscosity 12·5 minutes; freezing point 5° C.

5. Viscosine (valvoline), specific gravity 0·925 to 0·935, flashing point 290° to 310° C.; viscosity at 100° C. 5 minutes.

6. Residuals for manufacture of lubricating oils, specific gravity 0·908 to 0·916; flashing point 160° C.; viscosity at 50° C. 6 to 10 minutes.

E. *Fuel Oils*: Mazout, residuals, lake oil, specific gravity 0·895 to 0·935; flashing point (open test) not below 70° C.

F. *Goudron*, specific gravity not below 0·935, flashing point not below 270° C.

Coal Tar.—When a bituminous coal is submitted to dry or destructive distillation for the manufacture of coal gas it yields in addition to the latter a black viscous material known as coal tar and also coke.

The coal tar condenses in the gas mains and flows down into a large underground tank from which it is pumped to the stills.

The yield of coal tar varies with the nature of the coal and the method of distilling, usually amounting to 3·4 to 6·9 per cent.

Coal tar is a viscous black liquid having a “gassy” odour. It has a specific gravity of 1·1 to 1·2, and does not mix with water but is readily soluble in benzene.

Coal tar is used only to a limited extent in the manufacture of common wheel greases.

The composition of coal tar is extremely complicated, a very large number of compounds having been isolated from it. The following list includes only the better known products, as quite a number of derivatives of the compounds mentioned have also been found to be present:—

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4. Cylinder oil, specific gravity 0·911 to 0·920; flashing point 210° to 245° C.; viscosity 12·5 minutes; freezing point 5° C.

5. Viscosine (valvoline), specific gravity 0·925 to 0·935, flashing point 290° to 310° C.; viscosity at 100° C. 5 minutes.

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F. *Goudron*, specific gravity not below 0·935, flashing point not below 270° C.

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The composition of coal tar is extremely complicated, a very large number of compounds having been isolated from it. The following list includes only the better known products, as quite a number of derivatives of the compounds mentioned have also been found to be present:—

CHIEF CONSTITUENTS OF COAL TAR (LUNGE).

1. Methane Series of Hydrocarbons, C_nH_{2n+2} .

	Formula.	Melting Point.	Boiling Point. °C.
Methane	CH_4	Gaseous	—
Ethane	C_2H_6	"	— 20
Propane	C_3H_8	"	+ 1
Butane (normal)	C_4H_{10}	"	37
Pentane (normal)	C_5H_{12}	"	30
" (iso)	C_5H_{12}	Liquid	69
Hexane (normal)	C_6H_{14}	"	98
Heptane (normal)	C_7H_{16}	"	90.3
Ethylisoamyl	C_7H_{16}	"	119-120
Octane I.	C_8H_{18}	"	124
" II.	C_8H_{18}	"	130
Nonane I.	C_9H_{20}	"	150.8
" II.	C_9H_{20}	"	158-161
Decane I.	$C_{10}H_{22}$	"	170-171
" II.	$C_{10}H_{22}$	"	180-182
Undecane	$C_{11}H_{24}$	"	200-202
Dodecane	$C_{12}H_{26}$	"	218-220
Tredecane	$C_{13}H_{28}$	"	236-240
Quatordecane	$C_{14}H_{30}$	"	258-262
Quindecane	$C_{15}H_{32}$	"	280
Sedecane	$C_{16}H_{34}$	"	250
Solid paraffins	$C_{17}H_{36}$ to $C_{27}H_{56}$	40°-60°	

2. Ethylene Series of Hydrocarbons, C_nH_{2n} .

	Formula.	Melting Point.	Boiling Point. °C.
Ethylene	C_2H_4	Gaseous	— 110
Propylene	C_3H_6	"	— 5
Butylene (normal)	C_4H_8	"	+ 1
Pseudobutylene	C_4H_8	"	— 8
Isobutylene	C_4H_8	"	+ 39
Amylene	C_5H_{10}	Liquid	69
Hexylene	C_6H_{12}	"	98
Heptylene	C_7H_{14}	"	

3. Acetylene Series of Hydrocarbons, C_nH_{2n-2} .

	Formula.	Melting Point.	Boiling Point. °C.
Acetylene (Ethyne)	C_2H_2	Gaseous	—
Allylene (Allene)	C_3H_4	"	—
Crotonylene (Butyne)	C_4H_6	Liquid	18
Valerylene (Pentyne)	C_5H_8	"	51
Hexaxylene (Hexyne)	C_6H_{10}	"	80
Dodecylidene	$C_{12}H_{22}$	"	210
Tetradecylidene	$C_{14}H_{26}$	"	240
Hexadecylidene	$C_{16}H_{30}$	"	280

4. *Benzene Series*, C_nH_{2n-6}

	Formula.	Melting Point.	Boiling Point. °C.
Benzene	C_6H_6	Liquid + 5°	81.1
Toluene	C_7H_8	"	111
Xylenes :—	C_8H_{10}	"	—
Ortho	—	"	143
Meta	—	"	139
Para	—	15°	138
Pseudocumene	C_9H_{12}	Liquid	168
Mesitylene	C_9H_{12}	"	164
Hemellithene	C_9H_{12}	"	175
Durene, etc.	$C_{10}H_{14}$	80°	190

5. *Naphthalene Series*, C_nH_{2n-14} .

	Formula.	Melting Point.	Boiling Point. °C.
Naphthalene, etc.	$C_{10}H_8$	80°	218

6. *Anthracene Series*, C_nH_{2n-20} .

	Formula.	Melting Point.	Boiling Point. °C.
Anthracene, etc.	$C_{14}H_{10}$	213°	360

7. *Phenols*.

	Formula.	Melting Point.	Boiling Point. °C.
Phenol or Carboic acid	C_6H_5OH	41°	184
Cresols :—	C_7H_7OH	—	—
Ortho	—	31°	188
Meta	—	3°	201
Para	—	36°	198

8. *Naphthols*, $C_{10}H_7OH$.

	Formula.	Melting Point.	Boiling Point. °C.
Alpha	—	95°	282
Beta	—	122°	288

9. Nitrogenous Bases.

	Formula.	Melting Point.	Boiling Point. °C.
Pyridine etc.	C_5H_5N	Liquid	115

Coal tar is distilled in large iron retorts set in brickwork and heated by an open fire, Fig. 10; in some cases continuous retorts are employed in which there is a constant flow of the oil from one chamber to another in a vertical

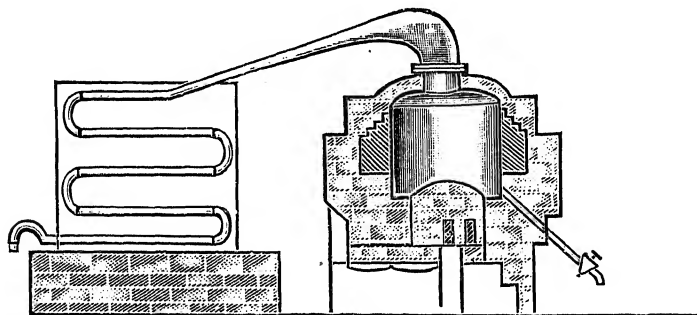


FIG. 10.—Coal tar still.

column. The vapours are condensed in a coil of iron pipes kept cool by a constant flow of cold water. In the early part of the distillation up to a temperature of 100° C. the "first light oils" pass over together with water and ammonia, this period being marked by unsteady ebullition, after which the distillation proceeds very regularly, the "second light oils" passing over till a temperature of 210° is reached, when the distillate is run into another receiver. "Carbolic oils" pass over between 210° and 240° , creosote oils from 240° to 270° , and anthracene oils above 270° . The distillate is stopped when sufficient has passed over, leaving a residue of "asphalt," "soft" or "hard" pitch according to the amount left in the still.

Coke oven tar is somewhat similar to gas tar, but

with a greater proportion of the creosote and anthracene oils; in ordinary coal tar these amount to about 8.6 and 17.4 per cent. respectively, whereas in coke oven tar the proportions are about 14.5 and 27.3 per cent. respectively.

Coal-Tar Oils.—The coal-tar oils most suitable for the manufacture of lubricating greases are those known as “anthracene oils,” boiling between 300° and 360° C., but it is necessary to remove all traces of phenols or “acids” by treatment with soda. They are then cooled to a low temperature and the solid naphthalene and anthracene separated out by filter pressing. The oils have a very high gravity, exceeding 1.0 and low solidifying or setting point, *i.e.* below -10° C. On heating to a high temperature they form very viscous products. During the war large quantities of this oil were manufactured in Germany, and it is estimated that 150,000 tons of the oil could be produced annually in that country.

For the manufacture of greases the expensive process of refining with alkali need not be resorted to as the acids can be neutralised by the addition of lime.

Shale Oils.—The manufacture of oils from bituminous shale by distillation has been practised for a long period on a small scale. In 1694 a patent was granted to Hancock, Portlock and Martin Eele for the manufacture of “pitch, tar and oils” from a kind of stone. Messrs. Betton of Shrewsbury, in 1716, and also the Earl of Dundonald, in 1781, were engaged in the distillation of illuminating oil from shale. In 1824 patents were granted in France to M. Cherveau and in 1832 to MM. Blum and Moneuse for a similar purpose. At the factory of the latter at Autun, Saône-et-Loire, the distinguished chemist, Laurent, and subsequently Selligne considerably improved the method of distillation and subsequent purification of the oil, the latter during the years 1838-43 producing about 15,000 barrels of oil.

The modern development of the shale oil industry, however, is entirely due to the labours of James Young of Glasgow. Young's attention was first drawn in 1847 by Dr.

Lyon Playfair to an exudation of petroleum in a coal mine near Alfreton, Derbyshire, and on examining this oil found it to contain solid paraffin, which at that time was a comparatively unknown substance, and he immediately established a works for refining the oil and extracting the paraffin. The supply of oil, however, became exhausted in a few years. Young then commenced the manufacture of oil from coal and shale and took out a patent in 1850 for the manufacture of "paraffine or an oil containing paraffine" from bituminous coal. The Young's Mineral Oil Company's works at Addiewell and Bathgate in Scotland soon became famous, and other companies were started with works situated in Midlothian and Linlithgowshire, Lanarkshire, Fifeshire, and Ayrshire. The industry grew very rapidly so that in 1873 7000 men were employed, the amount of shale distilled being 800,000 tons, yielding 30,000,000 gallons of crude shale oil, which on treating produced 12,000,000 gallons of refined oil, together with naphtha, paraffin, and other products.¹

At the Bathgate works the material distilled was known as Boghead or Torbanehill mineral, which was more of the nature of a cannel coal than a shale, as it yielded a remarkably high percentage of illuminating gas and also a considerable amount of oil and paraffin. This material has, however, been long exhausted.

The yield of oil from various materials is given in the following table (page 73).

A considerable amount of oil shale is now distilled in Australia.

¹ *Chemistry as Applied to the Arts*, p. 581.

SUBSTANCES USED IN THE PREPARATION OF LUBRICANTS. 73

Yield of Crude Oil, etc. from Various Products (Gesner).

Locality.	Volatile Matter Per Cent.	Coke Per Cent.	Yield of Crude Oil Per Ton.
<i>England.</i>			Gallons.
Derbyshire	48.36	53	82
Wigan (cannel)	44	56	74
Liverpool „	39	61	50
Poole (shale)	42	58	50
Newcastle	35	65	48
<i>Scotland.</i>			
Boghead	70.10	29.90	120
Cannel	38	62	40
Lesmahagov	51	49	96
<i>Colonial.</i>			
Albert coal, New Brunswick	61.05	30.65	110
Asphalt rock	43	57	64
Pictou (shale), Nova Scotia	27	73	47
<i>America.</i>			
Breckenridge	61.0	38.55	130
Onachita river (Askansas)	60	40	64
Ritchie County, Virginia (bitumen)	—	—	170
Bitumen, Cuba	71	29	120
„ Trinidad	38	52	70
„ Canada	70	30	118
Illinois (gas stone)	26	Limestone	18
California	70	30	116

In the shale oil works the following products are manufactured:—

	Density.
1. Sulphate of ammonia	—
2. Gasoline	0.660
3. Naphtha	0.730
4. Lamp oil	0.800-0.830
5. Lighthouse oil	0.870
6. Lubricating oil	0.870-0.880
7. Oil for gas manufacture	0.900-0.910
8. Green oil	0.915-0.930
9. Paraffin	—
10. Tar	—
11. Coke	—

The yield of products varies with the type of retort and the method of distillation. The following is the comparative yield of products obtained by distilling 1 cubic metre (1100 to 1200 kilograms) of the same French shale in French and Scotch retorts:—

	French Retort.	Scotch Retort.
Crude oil	40-70 litres.	100-125 litres.
Ammoniacal liquor	30-65 „	70-150 „
= Sulphate of ammonia	5-6 kilos.	10-11 kilos.
Permanent gas	25-30 cubic metres.	—
Paraffin	—	10 kilos.

The increased yields with the Scotch retort are due to the injection of superheated steam.

Coal shale is destructively distilled in horizontal or vertical retorts at a low red heat. The following particulars are mostly taken from an interesting account by D. B. Stewart of the shale oil industry as carried on at Broxburn.¹ The retorts used at Broxburn are Henderson's Patent Retorts of cast iron set vertically in the furnace. These are oval, 15 feet long and 24 feet by 1 foot in oval section, and are set in benches. The charge per retort is 18 cwt. of shale, which requires 16 hours for the distillation, the residue containing 12 per cent. of carbon is dropped into the fireplace and used as fuel. The permanent gases are also led to the fireplaces and burnt. The products are led off by a pipe at the bottom of the retort, and superheated steam is led in during distillation to lessen the decomposition of the oils by sweeping them out quickly. The gases are led to the mains and the condensers, the latter being a series of vertical iron pipes cooled by contact with the atmosphere. The products run from the condensers to storage tanks. Fans are employed to draw the gases through the apparatus.

Broxburn shale yields on distillation:

	Per Cent.
Volatile:	
Crude oil	12
Ammonia water	8
Permanent gas	4
	24
Non-volatile (spent shale):	
Combustible	9
Ash	67
	76
	<u>100</u>

An average Scotch shale gave on analysis the following figures:

	Per Cent.
Specific gravity	1.977
Moisture	2.54

The dry shale yielded:

Volatile matter	23.53
Fixed carbon	12.69
Ash	63.74
	<u>99.96</u>

¹ D. B. Stewart, *Jour. Soc. Chem. Ind.*, 1889, 101.

The yield of products per ton of shale is 30 gallons of crude oil, 65 gallons of ammonia water, and 2000 cubic feet of gas. The crude oil has a dark green colour and is semi-solid at the ordinary temperature but becomes fluid on gently warming. It has a specific gravity of 0·865 to 0·890.

The oil is distilled several times to obtain the different fractions, and the distillates are purified by treatment with sulphuric acid followed by caustic soda, and redistillation. The stills used for the separation hold 2000 gallons of oil and are connected in series of three with coking stills at each side and coil condensers. The flow of oil is continuous. The first fraction known as "green naphtha" has a specific gravity of 0·753, the second fraction 0·835, and the oils passing from the coking stills a specific gravity of 0·965. The capacity of a set of stills is 35,000 gallons per day. The crude oil distillation is a partially destructive one and the effect of the heat is restrained by the introduction of the right proportion of superheated steam introduced directly into the oil. The amount of paraffin found in the crude oil by Engler and Boehm's method is about 8 per cent. but quite 12 per cent. is extracted from the distillates. The heavy oils containing the paraffin are cooled by refrigeration and filter-pressed for the extraction of the paraffin. The paraffin scale in the cloths is subsequently purified by sweating out the more fluid product or by crystallising from naphtha.

The lubricating oils obtained from shale have a flash point between 320° and 400° F.

The following products are obtained from the crude oil:—

Brosburn Crude Oil.

	Per Cent.
Naphtha	5·0
Burning oils:—	
Petrolinc, specific gravity 0·800-0·812	
No. 1 Oil, " " 0·808-0·810	37·28
Lighthouse oil, " " 0·810	
Lubricating oils	17·40
Solid paraffin	12·52
Loss	27·80
	<hr/> 100·00

Young's Paraffin Light and Mineral Oil Cos.' Crude Oil.

	Per Cent.
Gasolene	0.25
Naphtha, specific gravity 0.700-0.706	5.75
Burning oils :—	
No. 1, specific gravity 0.802-0.804, Flash point 110°	38.00
No. 2, „ „ 0.810-0.812, „ 100°	
Crystal No. 1	
Lighthouse oil, specific gravity 0.810-0.820, Flash point 140°	
Lubricating oil	14.50
Paraffin	11.00
Loss	30.50
	<hr/> 100.00

In 1889 there were in Scotland fourteen companies, with a total capital of £2,000,000, engaged in the distillation of shale; nine of these carried on refining themselves, and the number of men employed was 10,000. The quantity of shale distilled equalled 2,000,000 tons per annum, yielding 60,000,000 gallons of crude oil, the value of the refined products being approximately £1,500,000.¹

Lignite Oils.—The bituminous lignite or brown coal found in the province of Saxony in the Halle district is distilled for the production of oils and paraffin in a similar manner to the Scotch shales.

The main product of the distillation is lignite tar which is yellowish-brown or dark brown in colour, melts at 25° to 35° C. and has a specific gravity of 0.850 to 0.910 at 44° C. On heating, the products commence to pass over at 80°, the main portions distilling between 250° C. and 350° C.

The tar is distilled in large cast iron retorts heated by fires either at the ordinary pressure, under a partial vacuum or with the aid of superheated steam.

The products obtained are :—

Water	small quantity
Crude oil	33 per cent.
Paraffin mass	60 „ „
„ grease	2 „ „
Red product	1 „ „
Coke	2 „ „
Permanent gas	2 „ „

The oil after chemical treatment is redistilled and separated into fractions according to gravity. Benzine, specific gravity

¹ Stewart, *ibid.*

0·790 to 0·810, boiling point between 100° and 200° C., flash point 25° to 35° C.; solar oil, specific gravity 0·830 to 0·840, pale vaseline oil, specific gravity 0·900 to 0·920, and paraffin mass from which paraffin is obtained by pressing, red oil or gas oil, etc., and a tarry residue, known as "goudron" used for fuel purposes.

The products obtained from lignite tar are as follows:—

Light lignite tar oil benzine, Sp. gr.	0·780-0·810	2-3	per cent.
Solar oil	0·825-0·830	2-3	" "
Heavy naphtha	0·848-0·880	10-12	" "
Gas oil	0·880-0·900	30-35	" "
Heavy oil	0·890-0·905	10-15	" "
Hard paraffin		8-12	" "
Soft "		3-6	" "
By-products (Creosote oil, etc.)		4-6	" "
Water, gas, and loss		20-25	" "

For further information on this subject see *Shale Oils and Tars*, by Dr. W. Scheithauer (published by Scott, Greenwood & Son).

Rosin.—Quite a number of resinous products occur in commerce, the products of various trees, but the only one used in compounding lubricants is common rosin which is obtained from various species of pine, fir, and larch by cutting through the bark. From the wounds thus made a semi-fluid gum resin exudes known as turpentine or galipot. This material is collected in cups, and when sufficient has accumulated it is distilled over a fire by the aid of a current of steam, when spirits of turpentine passes over, leaving the rosin in a molten condition in the still, from which it is tapped off into barrels.

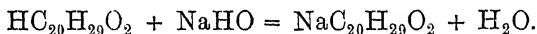
The greater part of the rosin on the market comes from the United States, being the product of several species of pine, mostly the swamp pine, *Pinus palustris* or *P. Australis*. French rosin is obtained from *P. maritima*. The natural turpentines yield 75 to 80 per cent. of rosin and 15 to 20 per cent. of volatile oil. The rosin varies in colour from very pale yellow to dark brown or almost black and is transparent to opaque. It has a peculiar fragrant odour, breaks with a conchoidal fracture, and is easily pulverised. It usually contains some impurities such as particles of wood bark, etc.

Rosin has acid characters and is largely composed of abietic acid ($C_{19}H_{28}O_2$) or sylvic acid ($C_{20}H_{30}O_2$); by some it

is regarded as being composed of the two acids dextro- and lævo-pimaric acids ($C_{20}H_{30}O_2$), while others assume that its chief constituent is an anhydride of one or other of these acids.

When rosin is heated with solutions of caustic soda or caustic potash it forms easily soluble salts which are known as rosin soaps. In the solid state these are soft and pasty and cannot be used alone, but in association with fats it yields cheap and excellent yellow bar soaps which are employed on a very large scale for household purposes.

Rosin behaves as a monobasic acid, therefore its combination with soda may be represented by the following equation:—



The saponification value of rosin is about 170, therefore 100 parts of rosin will require about 17 parts of caustic potash or about $12\frac{1}{2}$ parts of caustic soda for complete neutralisation. Rosin will also form soaps by heating with solutions of the alkaline carbonates, carbonic acid being evolved. 100 parts of rosin would require 21 parts of carbonate of potash (K_2CO_3), 16.3 parts of carbonate of soda (Na_2CO_3), or 43.4 parts of washing soda, $Na_2CO_3 \cdot 10H_2O$, for complete neutralisation.

Rosin may also be made to combine with lime or oxide of lead, etc., by heating them with the rosin and water, but as this is a rather slow process the insoluble rosin soaps are usually prepared by double decomposition, using solutions of an alkali rosin soap and a salt of the metal, when the insoluble rosin soap separates out and is collected on a filter cloth and dried.

The lime soap is very often used in preparing viscous lubricants such as cart greases, etc. On heating it with mineral oils it dissolves, yielding a clear, very tenacious, sticky product.

Rosin Oils.—When a rosin is heated above its melting point it begins to decompose and liberates gases and vapours, the latter condensing, when cooled, into liquid and solid products. This decomposition by heat is known as “dry or destructive distillation,” and is performed on a large scale in the case of

pine rosin. The oily products thereby obtained are known in commerce as resin oils, or rosin oils.

These oils consist chiefly of hydrocarbons, with which a varying amount of acid substances is always associated, which acid substances would corrode the metal of machine parts and form thick or soapy compounds, greatly retarding the work of lubrication.

In order to obtain a rosin oil free from these objectionable properties, the distillation process must be conducted in such a manner that the distillate is entirely free from acids. This is accomplished by adding a proportion of quicklime to the rosin in the still, this addition fixing the acids already present in the rosin or formed during distillation, and allowing a rosin oil to distil over perfectly free from acids, and therefore capable of being used as a lubricating oil without risk.

Since the introduction of large quantities of excellent American rosin at low prices into the European market, this substance has been extensively used, and the dry distillation of this rosin is made to furnish a whole series of chemical products, used partly for lighting, as solvents in varnish-making, as asphalt substitutes, and finally as a very important ingredient of many lubricants. The quantity of the products obtained by distilling a given weight of rosin varies according to the speed of distillation, and also according to the nature of the rosin itself. As a general rule, 1000 parts by weight of rosin will furnish—

Light rosin oil and acid liquor	88-100
Heavy rosin oil	730-800
Asphaltic residue	110-182

The proportions of the products vary according to the nature of the rosin and the conditions of distillation. Thus by quick and slow distillation the following results were obtained :—

	Quick Distillation. 1350 Parts of Rosin Yielded.	Slow Distillation. 1325 Parts of Rosin and 13 Parts of Lime Yielded.
Rosin spirit	30 parts	30 parts
Blonde oil	975 "	250 "
White oil	—	400 "
Blonde oil	—	160 "
Blue oil	100 parts	140 "
Green oil	—	80 "
Pitch and loss	221 parts	278 "

The volatile distillates, consisting partly of unaltered oil of turpentine that was present in the rosin, are used for lighting purposes, and as an excellent solvent for rosin in varnish-making. The heavy oil is refined by repeated fractional distillation and treatment with soda lye, the crude rosin oil having a disagreeable smell, a yellow to brownish colour, and a blue or green fluorescence. In refining the light rosin oil, the products comprise pinolin and a violet oil which changes to blue in the air—the so-called train oil or cod oil, which forms a very important component of many lubricants.

Rosin oils have a high specific gravity and a characteristic odour; they are also strongly fluorescent. They consist to a large extent of hydrocarbons with a lesser or greater proportion of rosin acids, which may have distilled unchanged or may have been formed during the distillation. They are usually known as “soft,” “medium” and “hard” oils according to their characters, the hard oils containing more acid than the soft.

Lewkowitsch¹ gives the following particulars of these oils:—

	Specific Gravity at 60° F.	Rosin Acids, Calculated to Combining Weight 346. Per Cent.
Soft	0.9878	9.2
Medium	0.9946	26.3
Hard	0.9974	31.2
”	0.9877	19.6
”	0.9890	20.3
”	0.9982	18.6
Siccative	0.9955	4.9
Extra hard	1.0115	18.4

On heating rosin oil with lime the acids combine with it, yielding lime soaps which thicken the oil. Rosin greases are thus prepared by heating a mixture of rosin oil, mineral oil and dry slaked lime.

Both solid and liquid lubricants can be prepared from rosin oil, and, by the addition of suitable adjuncts, the consistency can be varied to any desired degree. This constitutes a great advantage for the various purposes the rosin oil is intended to serve.

¹*Chemical Technology and Analysis of Oils, Fats and Waxes*, 1913, Vol. I., p. 609.

Thus, by the addition of suitable quantities of alkaline earths, rosin oil can be modified to form viscous to semi-solid masses. The alkaline earths employed for this purpose are calcined magnesia and lime.

For reasons of economy, however, the use of calcined magnesia has been abandoned, since the same results can be obtained by the cheaper and more easily procurable lime.

The Preparation of Rosin Oil.—Rosin oil is so extensively used in the production of lubricants that it seems advisable for manufacturers who are working on a large scale to prepare this ingredient themselves and sell the by-products. Originally the stills used for distilling rosin were of the usual simple form, heated by direct fire and connected with an ordinary condensing coil. Owing, however, to the fact that rosin is a very poor conductor of heat, the melted rosin at the bottom of the still easily became overheated, with the result that a large quantity of gas and pitch, but only a comparatively small amount of rosin oil, was produced.

To overcome this defect it is preferable to distil the rosin with the assistance of superheated steam exclusively, since this method gives the highest yield of rosin oil and entirely obviates the fire risk which is so imminent in the case of stills heated by direct fire.

When low-pressure steam ($1\frac{1}{2}$ to 2 atmospheres) is passed through a coiled pipe mounted in a furnace and heated to redness, steam at a temperature of 350° to 400° C. is easily obtained, *i.e.* much higher than is needed for the distillation of rosin. When this steam is passed in a suitable manner through the still, it will accomplish the dry distillation of the rosin; the operation can also be kept under perfect control by increasing or diminishing the supply of steam. A still for distilling rosin by superheated steam is shown in Fig. 11, means being provided for separating the distillation products according to their different boiling points.

The high cylindrical still is set in brickwork, so that the hot gases from a fire underneath (but out of direct contact with the still) can circulate round the still walls. The fire is used for heating the superheated pipes, the hot gases not being passed through the flues surrounding the still until

they have traversed the superheating chamber. The superheated steam traverses a coiled pipe mounted inside the still and discharging near the hood of the latter. It is also advisable to have a circular, perforated steam coil in the bottom of the still, so that superheated steam can also be forced through the mass of melted rosin.

The distillation products traverse a system of condensing U-tubes, the bottom connections of which are fitted with draw-off tubes for the condensed distillates. The least volatile products condense in the tubes nearest the still, whilst the lighter distillates are condensed in the water-cooled tubes farther away, and the lightest of all in the condensing coil, leaving the gaseous products alone to escape from the

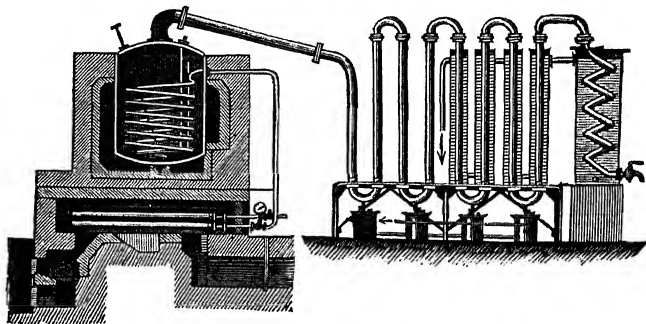


FIG. 11.

latter. These gases being combustible, are utilised by burning them under the boiler.

In order to reduce the waste of material to a minimum in the dry distillation of rosin, it is advisable to raise the temperature of the molten rosin gradually, and continue the heat until the amount of distillate passing over is found to have become very small.

Paraffin is a semi-transparent wax-like solid obtained by cooling the high boiling point fractions of shale oil and petroleum and filtering off the "scale". The paraffin wax is then purified by dissolving in hot petroleum naphtha and allowing to crystallise out by cooling. Crude petroleum yields about 2 per cent. of paraffin, while shale oils yield about 12 per cent. The specific gravity of paraffin varies

from 0.8236 to 0.940 and its melting point ranges from 28° to 62° C. The paraffins of high melting point are obtained by the partial liquefaction of cakes of paraffin in stoves kept at certain temperatures, so that the more fluid portions are liquated out and flow away. By this means paraffin of any desired melting point may be obtained.

Paraffin consists of the higher members of the paraffin series of hydrocarbons from $C_{15}H_{32}$ upwards.

Melted paraffin mixes easily with oils in all proportions, the products becoming pasty on cooling.

Mixed with heavy petroleum oils it forms "petroleum jelly," an artificial product resembling "vaseline" in appearance but differing from that material in the fact that on standing the oil gradually separates out.

Paraffin is used in the preparation of many lubricating greases, imparting body and consistency to these products.

Solid paraffins or "ceresins" of very high melting point, from 61° to 78° C., are obtained by treatment of the mineral "ozokerite" with boiling sulphuric acid, the residue being filtered through animal charcoal to decolorise it. The yield is about 70 per cent. The specific gravity of ozokerite paraffin or ceresin varies between 0.918 and 0.922.

A similar material known as "montan wax" is obtained from lignite.

Asphaltum is obtained from the pitch lake of Trinidad, from the Dead Sea, Altona in Albania, Coxitambo in South America, etc. It is a blackish-brown substance, hard and brittle, and breaking with a lustrous conchoidal fracture. Its specific gravity is 1.00 to 1.20 and on heating it melts to a black fluid at a moderate temperature. Asphaltum is soluble in turpentine and benzene and is employed in the manufacture of black varnishes, particularly that known as Brunswick black. It is not much used in the manufacture of lubricants. It is regarded as formed by the oxidation of petroleum.

Caoutchouc or *Indiarubber* is obtained by coagulating the "milk" which exudes on wounding the rubber tree (*Hevea Brasiliensis*), a native of Brazil, and from other trees. Much of the rubber now obtained, known as "plantation rubber,"

comes from large plantations under cultivation in Java, Sumatra, and the other islands of the Malay Archipelago. Indiarubber is a hydrocarbon ($C_{10}H_{16}$), being regarded as formed by the polymerisation of isoprene (C_5H_8). It is not directly soluble in oils, but by heating with them to a high temperature may eventually dissolve after decomposition. It swells up and eventually dissolves in coal tar naphtha and in carbon bisulphide.

Guttapercha is a similar product obtained from *Dichopsis gutta*, a tree growing in the Straits Settlements and the Malay Archipelago. Guttapercha consists also of a hydrocarbon ($C_{10}H_{16}$), together with its oxidation products. It differs from rubber in that it is not elastic and that it becomes pasty on heating in boiling water and can then be readily moulded, becoming hard again on cooling.

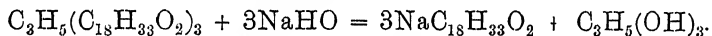
Both indiarubber and guttapercha have been used in preparing lubricating oils with the idea of rendering them more viscous, but it is doubtful if they have any real value.

CHAPTER IV.

SUBSTANCES USED IN THE PREPARATION OF LUBRICANTS (Continued).

SOAPS.

Soda Soaps.—When a fatty oil is heated with a caustic alkali it is “hydrolysed” or “saponified,” the glyceryl being replaced by the alkali metal so that salts of the fatty acids or “soaps” and glycerine result. The change which takes place may be represented by the following equation in which olein and caustic soda are employed :—



Soda soaps are solid at the ordinary temperature and are known as “hard” soaps, while the potash soaps are for the most part soft and pasty and are known as “soft” soaps. The characters of the soaps, however, vary very much according to the nature of the oils used in their manufacture. Oils are not pure glycerides of any one fatty acid, but usually two, three, or even more different fatty acids are present in each oil, nor is it usual, although there are a few exceptions, to employ any one fat or oil in soap making; usually two or more are employed in order to produce certain desired characters in the finished materials.

Castile or Marseilles soap is usually made from olive oil of commercial quality. It is a white, cream coloured or green very hard soap, easily soluble in water.

The original Castile soap had a reddish mottled appearance, due to the impurities, chiefly oxide of iron, in the “barilla” or sea-weed soda first employed. Since the introduction of the purer soda made by the Leblanc and other methods this mottling has been imitated, if one can call it imitation, by disseminating blue powder through the mass of

mottled soaps. These soaps are still extremely popular, although the mottling is merely a sentimental survival relating to conditions which passed away long ago.

The ordinary soaps are made from mixtures of tallow, cottonseed oil and palm oil. Tallow alone forms a very hard soap, cottonseed oil yields a soft soap, palm oil a medium hard soap. The three blend together very well. Coconut oil is easily saponified and yields a very hard soap, easily soluble in water. Castor oil also forms a hard soap, very easily soluble in water, but this soap is only used for special purposes.

Analyses of hard soaps are given below. It will be seen that commercial soaps contain a considerable proportion of water; freshly made soaps usually contain more than 30 per cent.

There are two ways of making soaps, the "cold process" and the "boiling process". In the cold process the fat or oil is heated to about 120° F. and the alkaline lye, which is a concentrated one, is brought to a temperature of about 80° F. The two are then intimately mixed and the mass is kept in a warm place for twenty-four to forty-eight hours when saponification will be complete and a hard soap results. This soap contains the glycerine and any impurities in the oils and fats. In the boiling process the oils are heated first with weak alkaline lyes and as saponification proceeds the lyes are strengthened until the soap is nearly fully formed, after which common salt is added, the soap being precipitated out in the form of curds which rise to the surface. The waste lye is then drawn off carrying in solution the whole of the glycerine and impurities, the soap is then "fitted" or finished by boiling with further additions of weak alkali until saponification is complete. Most of the hard soaps of commerce are made by the boiling process and are free from glycerine, which is recovered from the waste lyes by concentration and distillation.

Potash Soaps.—The potash or "soft" soaps are made by boiling oils with caustic potash lye until saponification is complete. The potash soaps cannot be salted out, hence they are evaporated until the mass forms a stiff jelly on cooling.

Soft soaps are usually made from oils, the best kind of soap from olive oil, but the principal oil used in their manufacture is linseed oil. Whale oil forms a good soft soap while the ordinary fish oils are employed in the manufacture of the commoner varieties.

Some of the soft soaps on the market are prepared from a soda soap by adding sufficient water to convert it into a pasty mass. The amount of water in such soaps may be 50 to 75 per cent.

The following are analyses of various kinds of soap:—

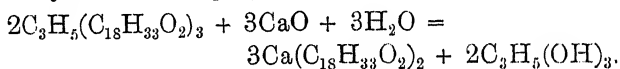
	Fatty Acids.	Neutral Fat.	Rosin.	Com- bined Alkali Na ₂ O.	Free Alkali Na ₂ O.	Glycerin, etc.	Salts.	Water.
Primrose soap .	47·32	0·46	16·16	7·12	0·25	—	0·21	28·48
Castile soap .	62·87	0·52	—	8·45	1·14	—	2·31	24·71
Cold-water soap .	45·12	—	22·36	9·27	0·34	—	0·58	22·33
Toilet soap .	84·24	—	—	10·40	—	1·32	0·31	3·64
Marseilles soap .	63·74	1·01	—	7·42	0·81	—	1·38	25·64
Tallow-curd soap	68·69	—	Silicate of soda	7·51	0·54	Colouring matter	1·25	22·01
Mottled soap .	46·79	—	2·14	5·61	0·48	0·82	1·21	42·95
Silicated soap .	68·50	—	3·45	7·28	—	—	0·62	20·15
			Silicate, carbonate, etc.					
" " .	30·49	—	10·98	4·78	—	2·66	—	51·09
Sizing soap .	26·50	—	—	3·81	—	—	0·42	69·27
Mottled soap .	49·28	1·54	—	6·28	1·49	—	4·98	37·43
" " .	65·50	—	—	7·28	0·46	—	—	26·76
Pale soap .	62·61	—	—	7·14	0·10	—	0·73	29·42
	Fatty and rosin			9·14	—	—	0·26	21·76
" " .	63·54	—	—	—	—	—	—	25·04
" " .	65·36	—	—	9·15	—	—	0·45	Water, glycerin, etc.
Soft soap:—				K ₂ O	K ₂ O			
London make .	46·00	—	—	8·43	0·42	—	—	45·15
Scotch make .	45·30	—	—	8·19	0·50	—	—	46·01

The question which soap to employ in compounding a lubricating grease will depend upon the consistency required in the finished product. Naturally where extreme stiffness is required the soda soaps will be employed. Tallow yields the stiffest soap; olive oil forms a very hard soap, but the latter is not so viscous as a tallow soap when dissolved in

water. Coconut oil and castor oil soaps have very little viscosity. It may also be well to remember that oleates combine better with mineral oils than do the stearates and palmitates, in fact the last two are insoluble, hence an olive oil soap will blend better than a tallow soap.

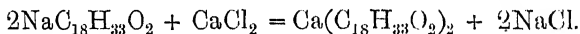
The ordinary yellow household bar soaps contain in addition to the fats and oils mentioned a certain proportion of rosin, usually amounting to about 25 per cent. of the total saponifiable materials. These soaps are cheap and they exhibit certain useful characters, notably easy solubility and great plasticity, which render them eminently suitable for preparing lubricating compounds.

Lime Soaps.—Lime soaps can be prepared by heating together a fat or oil, slaked lime and water, but this method is very slow and is rarely complete. The reaction may be shown by the following equation :—



Since lime has the same molecular weight as caustic potash, *i.e.* 56, the amount of quicklime required for completely saponifying 100 parts of oil would be 19.0 to 19.5, provided the lime was pure, which of course it never is.

A better method is to add to a slightly warm solution of a soda soap a solution of calcium chloride in slight excess when the lime soap separates in the form of insoluble curds :—

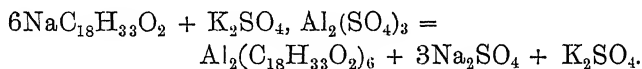


The soap is washed with water, collected on a filter cloth, pressed and dried.

Taking 100 parts of an ordinary soda soap containing 25 per cent. of water the amount of dry fused calcium chloride required to precipitate it would be 13.7 parts.

The soaps most suitable for this purpose are those of olive oil, linseed oil, rape seed oil, and rosin, since the calcium compounds of oleic, linolic, and generally of the liquid fatty acids, and rosin swell up or dissolve in mineral oils, whereas the calcium compounds of the solid fatty acids, palmitic, stearic, etc., do not. In the preparation of pasty or solid greases any soap may be employed.

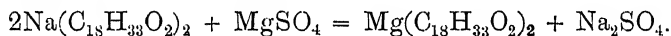
Alumina Soaps.—Alumina soap is prepared in a similar manner to the lime soap by precipitating a solution of a soda soap with a slight excess of alum :—



100 parts of an ordinary soap will require 39 parts of alum for complete precipitation.

Aluminium oleate is often used as a thickening agent for mineral oils.

Magnesia Soaps.—Magnesia soaps are usually prepared by precipitating a solution of a soda soap with a magnesium salt. Using magnesium sulphate (Epsom salts) the following equation shows the reaction :—



100 parts of an ordinary soap will require 30·4 parts of magnesium sulphate ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) for complete precipitation.

Magnesium oleate is also used for thickening mineral oils.

MINERAL SUBSTANCES.

Graphite or Black Lead.—Graphite is one of the forms of carbon which occurs as a mineral in various parts of the world. It was found of excellent quality at Borrowdale in Cumberland and was long used there in the manufacture of lead pencils ; it is also found in the Urals, Siberia, Canada, Ceylon, United States, etc.

Graphite is a dark grey foliaceous shining mineral, smooth and slippery to the feel and making a grey black mark when rubbed on paper. It has a specific gravity of 2·0 to 2·5 and consists almost entirely of carbon when pure ; usually, however, it contains more or less hard particles of the rock from which it is obtained and from which it is separated by levigation with water. For the purposes of lubrication it should of course be absolutely free from gritty particles.

Graphite is sometimes used alone as a lubricant, as for instance on the hoists used by well sinkers where wood rubs against wood, and also as a constituent in many lubricating greases.

acters of clay. By such addition the plasticity of the clay was increased 300 per cent., it required about 60 per cent. more water to impart to it an equal fluidity, while the particles of the clay became reduced to such a fine state of division that they remained suspended in water for an indefinite period and easily passed with the water through the pores of a fine filter paper.

On further investigation it was found that similar effects were produced on lampblack, graphite, alumina, amorphous silica and other mineral products; also that extracts of straw, oak bark, spruce bark, sumac, tea leaves, catechu, some forms of dextrin, and the gum of the cherry tree conferred similar properties.

Arising out of these investigations Dr. Acheson took out several patents for the "deflocculation" of amorphous materials including graphite.

The United States patents No. 884,989 of February 17, 1907, and 875,881 of January 7, 1908, relate to a method of "deflocculating" graphite, thus rendering it mixible with water, oil, etc., consisting in treating the graphite with a deflocculating agent such as gallotanic acid, the claim being made for this as a new product.

U.S. Pat. 384,698 of December 5, 1907, relates to the preparation of non-aqueous mixtures by first preparing a mixture of the amorphous substance with an aqueous solution of a deflocculating agent and subsequently displacing the water from such mixture with the non-aqueous liquid. Thus in the case of graphite, this is mixed to a paste with an aqueous solution of gallotannic acid which is then mixed with oil, the latter displacing the water thus forming an oil graphite mixture in which the particles of graphite remain permanently suspended. Subsequently Dr. Acheson named the aqueous graphite mixture "aquadag" and the oil mixture "oildag" and placed them on the market for lubricating purposes.

L. Archbutt¹ has analysed a sample of Acheson graphite, No. 1340, with the following result :—

¹ "Memorandum on Solid Lubricants," p. 12.

Moisture	0.07
Loss on heating to faint redness	0.23
Mineral matter	0.66
Graphite (by difference)	99.04
	<hr/>
	100.00

The mineral matter consisted mostly of alumina and oxide of iron, a little silica and lime.

Analyses of "aquadag" and "oildag" by the same author showed the former to contain about 15 per cent. of matter insoluble in water, mostly graphite, while the "oildag" contained about 10 per cent. of matter insoluble in ether, consisting mostly of graphite but containing some oil which was so firmly held that it was impossible to wash it out with ether.

The proportions of "oildag" recommended by the Acheson Graphite Co. to be added is 3 or 4 drops to 5 or 6 ounces of the oil. The two are shaken together and allowed to stand, when there should be no separation of graphite to the bottom of the bottle if the oil is suitable. Small quantities of electrolytes such as acids and alkalis cause precipitation of the graphite.

In a paper read before the American Electrochemical Society,¹ Dr. Acheson stated that an oil suspension containing 0.5 per cent. of deflocculated graphite was suitable for lubricating purposes. Comparative tests made by G. H. Benjamin with spindle oil containing the above quantity showed a decrease in the coefficient of friction of 65 per cent. as compared with the oil alone, while after 60 minutes' running the coefficient had dropped to 55 per cent. of that of the oil. At the end of this period the coefficient of friction with the oil alone increased to the extent of 54 per cent., while the increase with the graphite mixture amounted only to 30 per cent. After cutting off the supply of lubricant with the oil alone the coefficient of friction increased by 125 per cent. after 30 minutes' running, whereas with the oildag the rise increased only 14 per cent. in 80 minutes.

Dr. Acheson also states² that measurements of the de-

¹ *Electrochem. and Met. Indt.*, 1907, 5, 452-53.

² *Jour. Soc. Chem. Indt.*, 1911, 142.

flocculated particles by Mr. Alexander showed the average size to be 75 millimicrons, linear dimensions which suggests their approximation to molecular dimensions.

C. F. Mabery¹ has made comparative tests in a Carpenter's machine with hard Babbitt metal bearings, run at a speed of 450 revolutions per minute and at a pressure of 200 lb. per square inch. The bearings were first lubricated with one of the best motor lubricants at a rate of 8 drops per minute. After a run of 2 hours the supply of lubricant was stopped, whereupon the oil film broke in 17 minutes. With the oil-graphite mixture containing 0.35 per cent. of colloidal graphite under similar conditions, the coefficient of friction kept extremely low and very steady over a period of 5 hours. Oil containing 0.1 and 0.5 per cent. of colloidal graphite did not work so satisfactorily. The graphite appears to form a smooth or "graphoid" surface on the bearing, so that a lower proportion of graphite may be employed or less oil is needed, *i.e.* only $\frac{1}{10}$ as much as when the oil alone is employed. In the whole series of tests the maximum temperatures recorded never exceeded 65° C. "Oildag" is regarded as a very suitable lubricant for motor car engines, the "graphoid" surface formed on the bearings adding considerably to their wearing powers so that they last indefinitely. The chance of heating through irregular supply of the lubricant is entirely eliminated, while sudden strains on the bearings are better withstood than if an oil-film alone is present.

Tests on "oildag" have also been carried out on a Lancaster Gear Testing Machine at the instance of the Department of Scientific and Industrial Research,² which showed a slight gain in efficiency.

Steatite or Talc is a white, green or grey scaly or compact mineral which occurs in the Alps, in Tyrol, India, China, etc. It has a pearly or greasy lustre and a greasy feel, for which reason it is employed in the manufacture of lubricating greases. The specific gravity of the mineral is 2.56 to 2.80

¹ *Jour. Ind. Eng. Chem.*, 1913, 5, 717-23.

² "Report of the Lubricants and Lubrication Committee," *Department of Scientific and Industrial Research*, pp. 71 *et seq.*

and it has a hardness of 1·0. Talc is a hydrated silicate of magnesia, a sample from Tyrol having the composition silica 62·12, magnesia 31·15, ferrous oxide 1·58, and water 4·73 per cent. This corresponds nearly with the formula $H_2SiO_3 \cdot 3MgSiO_3$.

The name steatite is derived from *stear* the Greek word for tallow. Talc comes from the Swedish "taelga"—to cut, the mineral being easily cut with a knife.

Soapstone is an earthy variety of talc, a white mineral of fatty appearance, and so soft that it can be cut into thin pieces which will mark cloth; it is used in the manufacture of slate pencils and for tailor's crayons. In the state of powder it is used for dusting the insides of boots and shoes to make them slip on easily, also as a toilet powder for the skin.

Mica resembles talc in appearance but has a different composition, being a silicate of alumina and potash. It is in the form of glistening flexible scales and is harder than talc and not very suitable for use as a lubricant.

Sulphur is found naturally occurring in veins in volcanic districts, *e.g.* Iceland, Vesuvius, Lipari, and the Sandwich Islands. Large deposits of it are found in the United States, and it is also found running in veins through Tertiary strata as at Girgenti in Sicily. The rock, which contains 6 to 16 per cent. of sulphur, is mined and the sulphur obtained from it by melting it out in kilns.

Sulphur has a hardness of 1·5 to 2·5 and a specific gravity of 2·07.

Much of the commercial sulphur is obtained artificially by treating alkali waste with carbonic acid under pressure, as in the Chance process. Sulphuretted hydrogen is evolved which is burnt in kilns with a limited supply of air, and sulphur is thus deposited partly in the powdered state, known as flowers of sulphur and partly in a fused condition, the latter being run out into cylindrical moulds, and then appearing as round or oval rods, known as roll sulphur or brimstone.

Soda.—The ordinary soda of commerce is the carbonate of soda, which appears under three forms, as soda ash in powder, as crystal soda in very small crystals, and as washing

soda in very large transparent crystals which effloresce and become opaque on exposure to the air.

Soda ash is the anhydrous carbonate of soda, Na_2CO_3 , which is sometimes almost pure but usually contains caustic soda, and chloride and sulphate, with traces of oxide of iron etc.

Another form of carbonate, known as crystal carbonate, is almost pure, but contains one molecule of water, $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$.

Soda crystals ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$) contain a large proportion of water of crystallisation, amounting to 63 per cent., which it gradually loses on exposure to the atmosphere, becoming white and opaque. This form of carbonate is usually very pure, and being cheap, it is the form usually employed for a multitude of purposes. Soda crystals melt on heating in their own water of crystallisation and easily dissolve in water to form an alkaline solution.

When a solution of soda is shaken with a melted fat or oil it forms a milky liquid known as an emulsion. Caustic soda and caustic potash will also emulsify fats and oils but even more effectually.

In these emulsions the oils are suspended in the form of extremely fine globules throughout the aqueous liquid and the stability of the system is so perfect that in many cases no separation whatever occurs. The emulsions are, however, broken on acidifying the solutions or by the addition of electrolytes such as common salt.

Advantage is taken of the emulsifying power of alkalies in the manufacture of emulsion lubricants and lubricating greases.

Lime is the oxide of the metal calcium (CaO) and is made by heating limestone or carbonate of lime (CaCO_3) in kilns when carbonic acid is given off and quicklime remains. Lime is a hard white rock-like material which on adding water gives off great heat and slakes, forming a soft dry powder of slaked lime (CaH_2O_2), on adding more water, milk of lime is formed which contains the hydrate in suspension.

Lime is slightly soluble in water, 100 parts of water at 15°C . dissolving 0.136 parts of CaO ; the clear solution has an alkaline taste and is known as lime water.

Lime is often used in preparing lubricating greases; it hardens them and prevents their melting. Heated with oils and water it gradually saponifies them. The combination of lime with rosin acids—rosinate of lime—is also frequently used, and combinations of rosin oil and lime are the basis of many lubricating greases.

Litharge is the monoxide of lead (PbO) and is formed by oxidising lead on the hearth of a reverberatory furnace. There are two forms of this substance, flake litharge and powdered litharge. It is sometimes used for saponifying fats in the preparation of lard greases.

Lead Acetate, $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$, is formed by dissolving litharge in acetic acid. This compound has been used for hardening greases.

Ammonia, NH_3 .—In the ordinary state ammonia is a gas which is very easily soluble in water. The commercial ammonia is a concentrated solution of the gas in water which has a specific gravity of 0.890 and contains about 31 per cent. of NH_3 . Ammonia is a strong alkali and is sometimes used for neutralising oleic acid in the preparation of soluble oils and emulsion lubricants.

CHAPTER V.

SOLID LUBRICANTS.

As the chief ingredients of solid lubricants, two fats come into special prominence: animal tallow and palm oil. The latter, which is distinguished by its low price, is very largely used now for the preparation of machine greases.

To these fats, certain liquid animal and vegetable fats (train oil, rape oil, etc.) are added, to make the lubricants somewhat softer; a certain amount of soda is added, to convert the fats into emulsions, or they are partly saponified by the aid of soda lye. Finally, it is also possible, by the addition of inactive solid substances (which, of course, must be very finely ground), to thicken the lubricants for certain purposes, powdered soapstone, talc, and sulphur being employed in such cases.

By the suitable use of such adjuncts, any lubricant can be made to acquire the properties desired for a given purpose; and it is always advisable to prepare a stock composition which can then be easily modified in a suitable manner. In the present instance this stock composition consists of a mixture of fats, which may, if desired, be boiled with water and soda to form an emulsion.

The foregoing substances do not exhaust the list of products used for making solid lubricants; for certain purposes, advantage is also taken of other admixtures, such as paraffin, naphthalene, graphite, and also colouring matters, in order to impart a special colour to the product: or very peculiar combinations are prepared from caoutchouc, guttapercha, asphaltum, and other substances, though this class of lubricant has only a very restricted use.

Tallow Lubricants.—Tallow grease is always a serviceable article, but it is somewhat dearer than other lubricants.

Tallow changes in consistency very considerably according to the temperature. In the height of summer it is comparable with soft butter, but it is perfectly hard and friable in very cold weather. Owing to this behaviour, various railway companies—the Austrian State Railway for example—where this class of grease was used for the waggons and locomotives, employed different compositions of grease for each month. The relative proportions of these mixtures are given in the following table:—

For the Month of—	The Grease Consists of—		
	Tallow.	Olive Oil.	Pork or Horse Fat.
January	100	20	18
February	100	18	16
March	100	14	12
April	100	9	7
May	100	4	2
June	100	1½	1
July	100	1	½
August	100	1	1½
September	100	1½	2
October	100	4	3
November	100	8	7
December	100	14	12

More recently, the opinion has prevailed that there is no practical advantage gained from using so many different grades, and at present the railway mentioned has only three kinds of lubricant, namely, one for the winter, another for the summer, and a third for spring and autumn. These are compounded as follows:—

Grease for—	Tallow.	Olive Oil.	Old Grease, Pork, or Horse Fat.
Winter use	100	20	13
Spring and Autumn	100	10	10
Summer	100	1	10

(The old grease is the residue left in the grease boxes from the previous filling, and usually has the consistency of pork fat.)

These greases are prepared by melting the fats together and heating them to about 302° F., the mixture being kept stirred until this temperature is reached, whereupon the mass is left to set.

In working on the small scale, a simple tub is sufficient for this operation ; but for larger quantities it is advisable to melt the fats in a pan fitted with stirrers, Fig. 12. The liquid and more easily melted fats are placed in the pan first, the tallow being added last.

Train Oil Greases.—The cheap and abundant train oil obtained from the blubber of various kinds of whale, dolphin, and seal has not always received its true merits as a lubricant ; but in America, where the value of this oil is recognised, it is largely used for the purpose, many railways employing it for locomotives and axles, to the exclusion of all other greases.

To convert the dark-coloured and generally malodorous crude train oil into a good lubricant, it should be exposed to a low temperature, which, as previously mentioned, brings about the deposition of a considerable quantity of solid fat, after which it is treated with litharge to eliminate the free fatty acid present.

For this purpose the litharge is ground very fine, and is mixed with a small quantity of the train oil, being then put through a paint mill, just as in making paint, in order to produce a thick, viscous mass. This is then thinned down with a further quantity of train oil, and incorporated with the bulk by efficient stirring.

The liquid is next left to stand for a short time, whereupon the excess of litharge settles down in the form of fine sludge, whilst the newly formed compound of lead and fatty acid remains in the liquid, the viscosity of which it considerably increases.

Tallow and Train Oil Grease :—

Refined tallow	2 parts
Train oil	1 part

The tallow is melted, at a moderate temperature, in a pan, and as soon as it becomes fluid the train oil is added, the mass being crutched until a perfectly uniform mixture is produced.

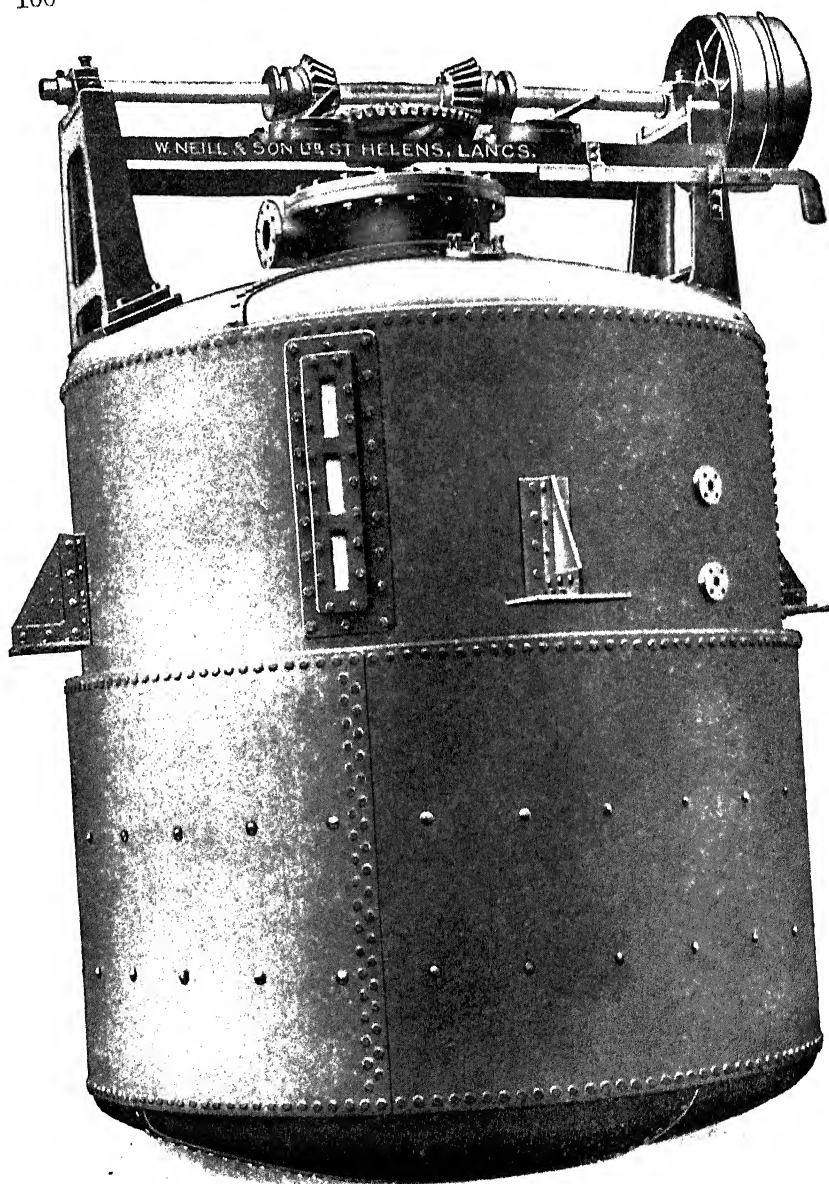


FIG. 12.—Jacketed mixer.

In making axle grease for cold countries, the proportion of train oil must be increased to impart to the grease the

palm oil, which is kept constantly stirred during the addition. After the whole of the soda has been added, the fire is drawn, and the mass is stirred until it begins to set and to offer considerable resistance to the stirrers.

The axle greases prepared according to these recipes are of excellent quality, and are still exclusively used on most English railways. The consistency can be altered as desired by varying the proportions of tallow and palm oil; if the former be increased, the grease is firmer and harder to melt, whilst an increase in the amount of the palm oil causes the product to melt at a lower temperature and imparts to it a softer consistency.

Tallow and Neatsfoot Oil Grease :

Tallow	100
Neatsfoot oil	100

This grease was used for a long time on the Württemberg railways: it is very stiff, and therefore specially suitable for summer use, but is comparatively dear.

Tallow, Rape Oil and Soda Greases :

1. *Winter Grease—*

Tallow	180
Refined rape oil	120
Soda crystals	20
Water	360

2. *Spring and Autumn Grease*

Tallow	230
Refined rape oil	85
Soda crystals	20
Water	360

3. *Summer Grease —*

Tallow	260
Refined rape oil	55
Soda crystals	20
Water	340

French Tallow and Train Oil Grease : —

Tallow	260
Train oil	230
Soda crystals	23
Water	500

Tallow and Castor Oil Grease : —

Castor oil	140
Pork fat	14
Tallow	7

This lubricant, though very useful, can only find restricted application for fine machinery, owing to the high price of the castor oil.

Palm Oil Greases.—A very large number of recipes for solid lubricants contain palm oil, the products being very widely used for greasing axles, railway wheels, flywheel shafts, and other heavy quick-running machine parts.

Palm oil lubricants have generally a pronounced yellow or orange colour, due to the use of unbleached palm oil, which, as already stated, is yellow to orange-red in colour.

Some greases are made of palm oil alone, unmixed with any other fat. Experience, however, has shown that these, though low priced, do not possess the properties expected of them. As a rule their melting point is too low; hence, under the influence of the heat generated by the movement of the machine parts, they become too fluid, thus entailing a considerable waste of grease, especially in the case of locomotive machines. Hence the simple palm oil greases are not very suitable for cart and railway axles, since these drip off the axles too readily, and waste to such an extent that their use would entail great expense for lubrication in the case of railways, etc.

Generally the palm oil receives an addition of tallow to raise the melting point of the mixture. Conversely, in the rare instances where it is desired to employ a lubricant with a low melting point, liquid fats, such as train oil or rape oil, are added.

These additions increase the cost of the palm oil greases considerably; but when the quality is taken into consideration, the improvement is so great that the cost is of comparatively small importance.

When the greasing of locomotive machinery is in question, such as cart and railway axles, where the recovery of the droppings is not so easily compassed as with stationary machines or marine engines, good results are obtained with compound palm oil greases. These are expensive to produce; but, in reality, they are cheaper than unmixed palm oil, since an equal quantity of the grease will last longer.

The mixed palm oil greases vary in composition to such

an extent that the proportion of added fats may range between 35 and 50 per cent.

Palm Oil and Soda Grease. All palm oil greases, to be serviceable, must contain a small addition of washing soda (crystallised sodium carbonate), since this ingredient determines the usefulness of the product.

As already mentioned, soda, like the other alkali carbonates and hydroxides (caustic alkalis), has the property of converting fats into emulsions. When soda solution is shaken up with any liquid or melted fat, the liquid gradually assumes a milky appearance. Under the microscope it appears to be colourless, but it is seen to contain innumerable fine globules of fat, distributed in the same way as butter is in milk.

The formation of these emulsions serves a double purpose: primarily, it enables a large quantity of water to be introduced into the lubricant, namely, the water in which the soda is dissolved. This greatly increases the bulk of the lubricant, without adding to its cost.

The second purpose served by the use of soda appears to be as follows: Palm oil consists largely of palmitin (a compound of palmitic acid and glycerine), which is a neutral fat, but also invariably contains a large quantity of free fatty acids, this being especially the case in old samples of the oil.

As already mentioned in treating of oleic acid, the free fatty acids have the property of strongly corroding metals, and for this reason pure palm oil greases have a very destructive effect on metals. However, when a sufficient quantity of soda is present in the grease, on the one hand, the neutral fat is emulsified; and on the other hand, the fatty acids having the property of displacing the carbonic acid from soda, and combining with the base to form the compounds known as soaps, the free acids are neutralised.

The property of combining with the free fatty acids, and even of extracting the fatty acids from fats, and combining with the former to form soaps, at the ordinary temperature, is also possessed by the caustic alkalis. So that if the soda be replaced by caustic soda, the whole of the fatty acids present in the free state will be at once saponified, during

the preparation of the lubricant, and on using the latter, there will be no danger of the machine parts being corroded in any way.

To convert soda crystals into caustic soda, the following simple operation may be performed:—

The quantity of soda to be used is dissolved in ten times its weight of water, and is boiled in an iron pan for several minutes with a quantity of slaked lime equal to that of the soda taken, the latter being thereby converted into caustic soda. The liquid is left to stand in the closed pan, and drawn off after the carbonate of lime has settled out.

Caustic soda can also be bought in the solid form, and when the price is low it can be used direct in the preparation of greases, the quantity required being about one-third that of the soda generally used. The method of procedure is just the same as with soda solution, but takes less time and it does not froth, the caustic alkali combining with the fatty acids more easily and quickly than the carbonate.

The Preparation of Palm Oil and Soda Greases.—The simple operation of preparing these greases is varied according to whether the quantity to be dealt with is large or small. For small quantities up to 2 cwt., the operation may be performed in an ordinary pan, mounted in brickwork and heated by direct fire. For larger quantities, it is advisable to employ steam as the heating agent, and to effect the stirring with mechanical appliances, instead of by hand.

Experience has shown that the quality of these greases is always better when they are prepared on the large scale. This can be accounted for by the fact that the larger mass of material retains its fluidity longer, so that a more intimate admixture is possible.

Operations are begun by placing the fat with the highest melting point (usually the tallow) in the pan first, and adding the palm oil when the first charge is melted, the two being then mixed completely by stirring, and raised to the temperature of boiling water.

The soda or caustic soda is dissolved in the prescribed quantity of water in a separate pan, heated to boiling, and poured into the molten fats, with continued vigorous stirring

If no vessel is available of sufficient size to hold the whole of the water needed to dissolve the soda, the latter is dissolved in a little water and added to the fats, the rest of the water being heated in the dissolving pan and run into the mixture by degrees. A still better plan is to dissolve the soda in several portions and pour the solutions one after the other into the fat.

The mixture of fats and soda solution must be stirred in such a manner as to ensure the uniform admixture of the two, which entails some little skill. The best way is to keep the fat in violent motion and then run the hot soda solution into it in the form of a thin stream.

Another very useful practice is to project both the melted fats and the soda solution through separate pipes so as to produce a fine jet of each inside the pan and then mix them by means of the stirrers.

Stirring is continued until the mass begins to thicken, and a trial sample sets completely within a short time. The finished grease is then ladled into receptacles holding a definite quantity, *e.g.* 14, 28, or 112 lb., and left to set therein.

Palm oil and soda greases are usually not brought into direct contact with the surfaces to be lubricated, but are generally put into grease boxes mounted immediately over the axles to be greased, and provided with a hole in the bottom through which the lubricant can find its way to the working parts.

Owing to the heat liberated by friction, the grease in the boxes is partially melted after the wheels have turned a few times, or at anyrate it will have softened enough to allow it to pass through the hole aforesaid and grease the axle. The best greases for this purpose are such as have a consistency resembling that of thick cream when slightly warm.

According to the time of year at which the grease is to be used, so must its composition be modified. If the temperature of the air - and consequently that of the machine parts to be greased - is high, the grease will melt too readily and will therefore become too fluid and run to waste. On the other hand, in cold weather the grease will keep very firm,

and the amount melted by the heat of friction may be insufficient for proper lubrication.

To obviate this difficulty, the proportions of the fats are adjusted for the various seasons; in summer, greases of high melting point are used, *i.e.* those containing a larger quantity of tallow; whilst for the winter, more readily liquefiable greases are employed, a smaller quantity of tallow being taken, and occasionally even a portion of the latter is replaced by a liquid fat, such as train oil or rape oil.

Some makers are not content with producing two varieties of grease for summer and winter use respectively; but also prepare a third grade suitable for spring and autumn. Indeed, such an intermediate grade is highly advisable for countries where the extremes of summer and winter temperature are great. For Italy, the south of France, England, and northern Germany, for instance, two grades of grease would be sufficient; but for south Germany with its hard winter, hot summer, and mild spring and autumn, three are advisable.

Recipes for palm oil and soda greases for the different seasons are given below; and it may be again stated that the melting point of these greases can be readily modified by altering the proportions of the fats of high and low melting point.

Yellow Palm Oil and Soda Grease:—

1. *For Winter Use:—*

Tallow	750
Palm oil	500
Sperm oil or rape oil	70
Soda crystals	228
Water	2600

2. *For Spring and Autumn Use:—*

Tallow	800
Palm oil	500
Sperm oil or rape oil	55
Soda crystals	222
Water	2500

3. *For Summer Use:—*

Tallow	900
Palm oil	500
Sperm oil or rape oil	44
Soda crystals	216
Water	2450

The lower the temperature, the more can the proportion

of the fat be diminished and the water increased, the converse being the case in summer. Train oil can be used instead of the dearer sperm or rape oil, but it must first have been specially treated.

When train oil is exposed to a moderately low temperature, *i.e.* about 40° F., a considerable quantity of hitherto dissolved fat separates out, the remaining liquid being more fluid than before and specially adapted for adding to the above greases, whilst the solid portion can be utilised in soapmaking or for the preparation of special lubricants.

Yellow Palm Oil, Soap, and Soda Greases: -

1. *For Winter Use -*

Palm oil	160
Soap	50
Soda crystals	16
Water	540

2. *For Summer Use*

Palm oil	160
Soap	50
Soda crystals	70
Water	360

The palm oil is first melted and then mixed with the soap; when this also is melted, the soda dissolved in 40 or 60 parts of hot water is run in and the mass well stirred, the remainder of the water being incorporated with the mass, which is kept hot throughout. When all the water is in the pan, the contents of the latter are poured into a vat and stirred until they begin to set.

Another way of preparing these greases is by melting the fat and soap together in a pan and mixing them by stirring. Rape oil, which is rather dear, may be replaced by an equal quantity of train oil. Horse fat is recommended by some, but raises the melting point of the grease more than the liquid fats.

The soda is dissolved in the necessary amount of water in a second pan, the solution being heated to boiling and then mixed with the melted fat in a third vessel by stirring, this being continued as long as the consistency of the mass will allow.

A better class of grease is compounded of palm oil and rape oil, the soda being replaced by a corresponding amount of caustic soda. This grease does not contain any emulsion, but

is a true soap grease, part of the fat being saponified by the caustic alkali.

American Palm Oil Greases:—

	A	B
Tallow	150	100
Palm oil	100	160
Soda crystals	25	35
Water	160	300

French Palm Oil Greases:—

	A	B
Tallow	380	280
Palm oil	125	100
Rape oil	65	70
Soda crystals	25	20
Water	420	500

Belgian Palm Oil Greases:—

	A	B
Palm oil	210	380
Tallow	—	750
Soap	85	—
Colza oil	—	200
Soda crystals	15	50
Water	700	1300

This grease, which is both cheap and efficient, is characterised by containing three fats: tallow, palm oil, and colza oil, in its composition.

Axle Greases for Very Heavy Waggon:—

1. *For Winter Use:—*

Tallow	420
Palm oil	840
Soda crystals	140
Water	4200

2. *For Summer Use:—*

Tallow	420
Palm oil	490
Soda crystals	35
Water	2300

The above are calculated for severe winter weather and high summer temperatures. For milder winter climates the proportion of soda may be somewhat reduced and the palm oil increased.

Cart Grease:—

Palm oil	210
Tallow	85
Soda lye	65
Water	920

The palm oil and tallow are melted together, the mixture

rendered uniform by stirring, and the soda lye added. The density of the latter should be 20° to 21° Bé., that is to say, the Baumé areometer should sink into the solution down to the 20° or 21° mark on the scale.

After the soda lye has been stirred in, the water is added, and the mass is stirred until uniform, whereupon it is ladled out into vessels to set.

Grease for Wooden Machinery:—

Tallow	.	.	.	.	.	.	.	.	.	30
Palm oil	.	.	.	.	.	.	.	.	.	20
Train oil	.	.	.	.	.	.	.	.	.	10
Graphite	.	.	.	.	.	.	.	.	.	20

The fats are melted by moderate heat, and the graphite, which has been reduced to the finest powder and then levigated, is intimately mixed with them by protracted stirring.

With regard to the quantities consumed, the palm oil greases may be regarded as the most important of all lubricants, since they are employed, to the exclusion of all others, on many railways, and are used also in large quantity on many large machines.

CHAPTER VI.

LEAD SOAP LUBRICANTS.

THE lead salts possess the property of saponifying fats or fatty oils to form fairly solid compounds, known as lead soaps, which are hard in the cold and pasty at the ordinary temperature, but attain the necessary degree of fluidity when warmed by friction.

This latter property is highly important in the case of the axles of vehicles, since it reduces to a minimum the loss of grease by dropping.

For the preparation of these lubricants it is first of all necessary to make a solution of basic lead acetate, or sugar of lead, which is then incorporated with a suitable proportion of fat.

The solution is prepared from:

Sugar of lead	10
Litharge	10
Water	110

these are boiled $1\frac{1}{2}$ to 2 hours, with repeated stirring, at the end of which time the mass is left to rest, and the clear liquid is drawn off. The latter is made up to 100 parts by weight, by the addition of water, and after being warmed to about 120° to 140° F., is mixed with common fat (rape oil and pork fat, or neatsfoot oil), in the following proportions :

Sugar of lead	100
Rape oil	80
Pork fat	80

The resulting preparation will be of a uniform grey colour, and when melted will set again at 85° to 105° F.

A large number of so-called "anti-friction greases," regarded as secret preparations, are in the main only lead soap prepared according to this recipe or on similar lines. Owing to its rather high melting point, this grease is less suitable

for ordinary carts than for quick-running axles (railway wheels, flywheel shafts, etc.).

The preparation of lead soap greases can be greatly simplified by proceeding in the following manner. The ingredients are :

Sugar of lead	20
Litharge	10
Water	225
Vinegar	1

The water and vinegar are placed in a covered vat, and the sugar of lead and litharge are placed in two linen bags and immersed in the liquid, being left therein for a week. The clear solution of lead acetate drawn off at the end of this time is placed in a vat and mixed with—

Rape oil	500
Pork fat	750

which have previously been melted together in a pan and heated to about 250° F. The mixture is well stirred and left to stand for several days. In from two to four days it will have set, and will then be ready for use.

Lead Oleate Axle Grease.—Palmer's Patent Axle Grease consists principally of lead oleate, and is therefore a lead soap, closely resembling apothecaries' sticking plaster in composition.

In the manufacture of stearine candles, the crude fatty acids are subjected to heavy pressure, which squeezes out oleic acid containing stearic acid and palmitic acid in solution. When the crude oleic acid is exposed to low temperatures a large proportion of the dissolved solid fatty acids crystallise out. The crude oleic acid of commerce is a yellow to brown liquid, mostly with a disagreeable smell. In Germany it is known as Oel—or Oleinsaure, and in France as acide oleique, both of which names express its composition ; but in England it is frequently called "tallow oil," a term which may give rise to confusion, inasmuch as the same name is (correctly) given to the oil obtained by pressing refined tallow that has been stirred before setting. True tallow oil is a much more valuable and expensive article than oleic acid. It is also known in this country as oleine in contradistinction to olein which is the neutral triglyceride of oleic acid (triolein).

In order to produce lead soap from oleic acid the latter is placed in a pan which is mounted on a brick work setting in such a manner as to prevent the contents coming into direct contact with the heating flame. The pan is also provided with a close-fitting lid, to prevent the flame spreading in the event of the oleic acid becoming ignited.

The oleic acid is heated to boiling, whereupon litharge, in a finely ground condition, is run in through a narrow pipe and stirred continuously. The usual proportion of litharge is from one-fifth to one-fourth the weight of the oil.

After all the litharge is in, the stirring is continued for twenty to forty minutes, the temperature being then gradually lowered. The litharge undissolved by the oleic acid settles to the bottom of the pan, and is left there until the next operation. The clarified liquid is ladled off and left to set, preferably in sheet-iron tanks.

On quick-running axles which generate a good deal of heat, this grease soon attains the requisite fluidity, but it is too stiff for those running at low speeds.

The melting point of this very useful lubricant is best lowered at the time of preparation by the addition of cheap fats like horse fat or train oil. The hot lead oleate obtained as above is ladled out into a separate vat, already containing the fat or train oil, and the mixture quickly stirred together. The lower the desired melting point, the larger must be the proportion of added fat. Consequently for summer greases a relatively large quantity of fat must be added, about 20 to 40 parts per 100 of lead oleate being usually sufficient.

CHAPTER VII.

TRUE SOAP GREASES.

THE soap greases, properly so called, are prepared with ordinary soft soap (a compound of potash with fatty acids), or from fats and potash, these forming the emulsions already referred to. Although these greases are occasionally very useful, their employment is restricted, owing to the risk that lack of care in their preparation may leave appreciable quantities of potash or caustic alkali uncombined, with consequent liability to injury of the metal, which may be extensively corroded.

Chardon's Soap Grease:—

Soft soap	.	.	.	.	.	.	.	.	.	10-50
Lye or water	.	.	.	.	.	.	.	.	.	90-50

This peculiar lubricant, which is claimed to specially lessen the wear and tear of the bearings—a claim which if it were tenable would be highly commendable—is, according to its inventor, much cheaper than oil. The proportions of soap and water vary with the season.

The use of lye, however, for dissolving the soap, appears objectionable, if only for the reason that caustic alkalis exert a corrosive action on some metals and metallic alloys—bronze, for instance—of which machine parts are generally made. In a properly made soap there is no free fatty acid, so that any added caustic alkali acts on the metal and soon causes it to corrode. That Chardon's grease is of little value is shown by the circumstance that, according to the recipe, it is immaterial whether water or lye be taken. Any one possessing even a slight knowledge of chemistry will know what a wide difference exists between a lubricant consisting of soap and water and one containing soap and lye.

Tallow, Oil and Soap Grease:—

Tallow	420
Olive oil	360
Potash	60
Water	650

The potash is dissolved in water, the solution heated to boiling, and the whole of the fat is added at once, the fire being made up so as to keep the whole in a fluid state. Boiling is continued, with constant stirring, until saponification is indicated by the thickening of the mass and the way in which a sample will draw into threads on cooling. The resulting product is really a dilute solution of potash soap mixed with an excess of fat, and may therefore be regarded as an emulsion lubricant in the true sense of the term.

Carriage Axle Greases:—

	A	B
Tallow	500	500
Linseed oil	500	450
Pine rosin	500	500
Caustic soda lye	315	500

Both preparations, when suitably stirred during preparation, form solid masses of the consistency of salve, and yellow in colour. They distribute easily on the axles and lubricate well. The rosin is melted first, the tallow and linseed oil being then added, and when these form a uniform mixture, the caustic soda lye is added gradually. The lye is used moderately strong, and the firmness of the grease can be heightened by increasing the concentration of the alkaline solution.

From the chemical standpoint this somewhat expensive lubricant is a mixture of ordinary soap, rosin soap, and emulsified fats.

CHAPTER VIII.

CAOUTCHOUC LUBRICANTS.

Doulon's Caoutchouc Grease :

Train oil	200
Caoutchouc	20

The train oil is heated in a pan until it begins to decompose (which condition is revealed by an ebullition resembling boiling and by the evolution of a disagreeable odour), the caoutchouc—cut into small pieces—being introduced by degrees and the entire mass vigorously stirred after each addition.

For ordinary purposes this grease is inapplicable, owing to the high price of caoutchouc; it may also be remarked that lubricants of at least equal efficiency can be prepared at a much lower cost.

Caoutchouc Machine Grease :

Caoutchouc	20
Linseed oil	1000

Twenty parts each of caoutchouc and linseed oil are first melted together, another 20 parts of oil being stirred in as soon as the mixture begins to disengage vapour. Subsequently the rest of the linseed oil is added, 100 parts at a time.

American Caoutchouc Grease :

Caoutchouc	4
Oil of turpentine	8
Rape oil	114
Soda	16
Glue	4
Water	50

The caoutchouc is dissolved in the oil of turpentine, whilst the rape oil is first mixed with the soda, water, and glue, and then boiled, the caoutchouc solution being stirred into the homogeneous mixture.

Strictly speaking, the caoutchouc is not dissolved in the turpentine, since very little, if any, of the caoutchouc is really dissolved, but merely remains in a highly swollen condition. The finished mass requires to be stirred for a very considerable time in order to get it perfectly homogeneous.

Caoutchouc Adhesion Grease:—

Caoutchouc	36
Oil of turpentine	72
Cabinetmaker's glue	10
Tallow	80
Soda	72
Water	900

This peculiarly compounded grease is prepared as follows: The caoutchouc is first dissolved in the oil of turpentine at a temperature of about 250° to 300° F., the tallow being melted in another pan, mixed with the powdered soda, and the water stirred in. When the whole has become homogeneous, the caoutchouc solution is run in, stirred, and the whole left to set.

Caoutchouc and Guttapercha Grease:—

Caoutchouc	50
Guttapercha	50
Oil of turpentine	100
Tallow	1000

The caoutchouc and guttapercha are dissolved in the oil of turpentine and heated strongly, the tallow being then added by degrees. The use of the expensive ingredients, caoutchouc and guttapercha, makes this a very expensive grease.

Caoutchouc Axle Grease:—

Palm oil	20
Train oil	100
Caoutchouc	2
Litharge	2
Sugar of lead	2

The caoutchouc is cut into small pieces and heated with the train oil to about 390° F., the litharge and sugar of lead being then added and the heating continued for an hour longer. Finally, the palm oil is stirred into the still hot mass.

Caoutchouc and Fat Grease:—

Caoutchouc	5
Palm oil	100
Rape oil	100
Tallow	50

The caoutchouc is dissolved in the rape oil by the aid of a high temperature, and the filtered solution is incorporated with the solid fats. The author has however found, by experiment, that filtration of the mass is impracticable, since it is difficult to strain it even through a linen cloth.

The value of caoutchouc and guttapercha greases is somewhat problematical. Statements have been made with regard to their economy in use which it would be difficult to substantiate, and certainly the rubber or guttapercha are in the majority of cases not dissolved but simply disseminated in a finely divided state, in which condition they can exert no more action than other inert insoluble substances.

CHAPTER IX.

OTHER SOLID LUBRICANTS.

THE following recipes relate to a few lubricants which do not belong to any of the foregoing groups, but have proved satisfactory in actual use. Recipes which gave unsatisfactory results when tried, or appeared from their constitution to be merely empirical compositions, have been omitted, since their inclusion would serve no useful purpose.

Asphaltum Axle Grease:

Asphaltum	.	.	.	.	.	.	.	.	.	32
Black pitch	.	.	.	.	.	.	.	.	.	8
Petroleum	.	.	.	.	.	.	.	.	.	8
Litharge	.	.	.	.	.	.	.	.	.	8
Water	.	.	.	.	.	.	.	.	.	80

The asphaltum and pitch are first melted together in a pan, the petroleum being then added until the mass has become uniformly fluid. The litharge is next added, and finally the water is run in in small quantities, the whole being stirred until perfectly uniform. The asphaltum and pitch impart to this grease a lustrous black colour and a peculiar, bituminous smell. The fluidity of the mass can be increased or diminished by correspondingly varying the proportion of petroleum.

Naphthalene Grease:

Naphthalene	.	.	.	.	.	.	.	.	.	100
Rape oil	.	.	.	.	.	.	.	.	.	50-100

The naphthalene—a crystalline hydrocarbon recovered from coal tar—is melted and stirred up with a larger or smaller quantity of rape oil, the product thus varying in consistency being solid and firm, semi-solid and pasty, or fluid as the case may be, and forming a useful lubricant. The expensive purified naphthalene is not required here, purity not being an essential feature for the purpose in view;

so that the crude article, which is more or less impure, is quite suitable for the purpose. These remarks apply equally to paraffin.

Rosin Machine Grease:—

Pine rosin	. . . . .	100
Rosin oil	. . . . .	50
Pork fat	. . . . .	300

The rosin and rosin oil are melted together, and the pork fat is stirred into the liquefied mass.

Graphite Axle Grease:—

Tallow	. . . . .	36
Pork fat	. . . . .	9
Palm oil	. . . . .	9
Graphite	. . . . .	2

Graphite is of a steely grey colour, and imparts a characteristic grey-black colour to the grease.

This graphite axle grease is a very efficient lubricant, and is frequently used in Belgium and England as the sole grease for waggon axles.

Graphite Grease for Quick-running Axles:—

Tallow	. . . . .	100
Graphite	. . . . .	100

This is specially suitable for greasing the shafts of circular saws, ventilating fans, etc., and indeed for any axles running at high speed under small load.

Colloidal Olein Lubricant.—According to de la Guéronnière, a special form of grease for lubricating purposes can be prepared by extracting the mucilaginous principle from the following marine plants: *Fucus crispus* 75 per cent., *fucus perlè* 20 per cent., agar-agar 5 per cent. (or the same proportion of lichen or other algæ that contain gelose). The woody matter of these plants is carefully removed, after which the plants are washed separately in hot water containing 10 per cent. of common salt and 5 per cent. of carbonate of potash. The next stage is to steep the washed plants in water containing 10 per cent. of salt, and to dissolve them by gradual boiling in water. According to the concentration required, 700 to 1000 parts by weight of the mixed plants are taken to 100,000 parts of water, for the preparation of colloidal olein, the amount being doubled in the case of

colloidal grease. The solution is filtered whilst hot, and is treated with about 800 parts of oil of turpentine, alcohol, sulphurous acid, phenol or some essential oil.

Cart Greases.—The preparation of cart greases is a profitable branch that can be established without much trouble; and any maker who will supply a good article can be sure of securing permanent customers, writes C. F. Borott, in the *Seifenhaendler*. Unfortunately, this class of grease lends itself readily to adulteration, so that preparations are met with in the market which are loaded to the extent of as much as 75 per cent. with water, asphalt, pitch, tar, heavy spar, levigated chalk, clay, soapstone, common graphite, etc. Of course, a far larger profit is made on such goods than on the genuine article, but no lasting connection is established, consumers going elsewhere when they find out the disadvantages attending the use of such trash. The following recipes, however, may be relied on to furnish satisfactory products: (1) Melt together, by stirring in a large pan over a moderate fire, 30 parts by weight of wool fat and 60 parts of dark vaseline oil. Then stir into this mixture $7\frac{1}{2}$ parts of lime that has been slaked to fine powder, and when this has been properly incorporated, add $3\frac{1}{2}$ parts of caustic soda lye (density 42° B.), continuing to stir and to warm the mass up to 50° to 60° C. until it is homogeneous and free from lumps. After drawing the fire, the grease is left to cool, with occasional stirring, and is then packed in kegs, tins, or boxes. The colour darkens with age, but may also be artificially deepened with a little lampblack. (2) Twenty-five parts of crude rosin oil are heated to 50° to 60° C. in a pan, and stirred up with 20 parts of fine slaked lime until the whole is a tough uniform mass, free from lumps. This stock can be reduced, according to requirements, by the addition of mineral oil or more rosin oil. It is advisable to pass the lime through a medium fine sieve. (3) A grease can be made, without heat, by mixing 60 parts of dark vaseline oil with 20 of slaked lime and 1 of lampblack, followed by 30 parts of crude rosin oil, the whole being stirred until properly mixed.

Palm Oil Waggon Grease.—10 lb. of palm oil soap is melted with an equal weight of palm oil; 550 lb. of rosin

oil is added and sufficient rosin oil soap to impart to the mass a consistency resembling butter; finally, $7\frac{3}{4}$ to 10 lb. of caustic soda lye is stirred in and the mass allowed to cool.

Waggon Grease.—Stir 90 lb. of slaked lime into 100 lb. of rosin oil, heat, and continue stirring until a uniform paste is obtained.

Wheel Greases.—Wheel greases of a common description generally have as their basis crude rosin oil, and can be made in a variety of ways, either with this oil alone or in an admixture with other oils and fats. The following formulæ are given to show how these can be made:—

20 lb. crude rosin oil and 16 lb. 900/7 American mineral oil are mixed together; then there is added 30 lb. fine whiting free from grit. This is done with constant stirring. There is then added 2 lb. fresh slaked lime mixed with $2\frac{1}{2}$ lb. soda crystal solution 32° Tw. The whole mass is stirred until it becomes stiff.

Another grease is made in the following manner: 80 lb. of American petroleum oil 900/7 is heated to 250° F., and 30 lb. pale rosin melted therein; to this mixture is now added 220 lb. American 900/7 oil and 60 lb. thick crude rosin oil; 60 lb. dry slaked lime is added, and the whole mass well stirred until it becomes homogeneous and stiff.

Another grease is made from 70 lb. thick crude rosin oil and 20 lb. thin crude oil, and the mixture is heated to 200° F., and 10 lb. dry slaked lime stirred in till the mass stiffens.

Another good wheel grease is made by boiling together 300 lb. brown Yorkshire grease with 60 lb. of caustic soda lye of 50° Tw. There is then added 300 lb. crude rosin oil and 30 lb. American 900/7 oil; after these are mixed there is added 130 lb. slaked lime of good quality. The whole mass is thoroughly stirred, and allowed to stand for twenty-four hours. The next day the mass is warmed up, and 100 lb. of American oil 900/7 is added until the mass is of the right consistence.

A very cheap grease of a black colour is got by taking 50 lb. coal-tar, heating to 250° F. for two hours, then allowing to cool down to 150° F., and adding 20 lb. tar-grease oil,

30 lb. crude rosin oil, and 10 lb. dry slaked lime, stirring well.

Another plan frequently followed is to take 100 lb. thick crude rosin oil, heat to about 150° F., then stir in 20 lb. quicklime, which is first slaked to a thick cream. The mixture is well stirred for a few hours, then placed on one side for twenty hours. Water will be found on the top of the mixture; this is poured off, and the grease heated to 120° F., and then mixed with constant stirring with 100 lb. soft crude rosin oil.

Solidified Oils.—Petroleum oils may be rendered much more viscous, and indeed quite solid, by heating them with a metallic soap such as oleate or rosinate of calcium, magnesium, or aluminium, which dissolve in the form of a colloidal solution rendering the mass much more viscous, so that it sets to a soft or stiff jelly according to the proportion of metallic soap added.

E. Lecocq (French Pat. 439,467, Jan. 25, 1912) uses for this purpose wool fat which has been neutralised with an alkali or alkaline earth, the product being incorporated with a sufficiency of a vegetable or animal oil, fatty acids, or hydrocarbon oil to produce a material with the desired melting point.

R. Demuth (Eng. Pat. 6165, Mar. 11, 1911) employs for this purpose a stiff paste prepared by dissolving a nitrogenous substance (*e.g.* casein) in ammonia, the proportions recommended being 1 to 2 parts of powdered casein, 5 to 7 parts of water, and sufficient ammonia to form a stiff paste on warming. The product thus formed is emulsified with an equal volume of a fatty oil and then incorporated with 10 times its weight of a petroleum oil.

Another process in which casein is employed is outlined in the patents of A. Dinsley (Eng. Pats. 11,129, July 31, and 14,520, Oct. 14, 1915); in this case 5 parts of casein are dissolved in 10 parts of caustic soda and 10 parts of water; this is stirred into melted tallow until the two are thoroughly incorporated and the mass is then allowed to cool. One part of this solid mixture is pulverised, mixed with 1 part of castor oil and 7 parts of a mineral lubricating

oil or petroleum jelly, and the whole heated and stirred until combination is complete, when it is poured into moulds and allowed to solidify. Solid lubricating materials, such as graphite, etc., may also be added if desired.

K. Engel (Eng. Pat. 11,934, June 26, 1911) proposed to replace tallow for lubricating purposes by employing sponges saturated with a heated fatty material which becomes solid on cooling. Such a material can be prepared by boiling rapeseed oil with a mixture of milk of lime and caustic soda till saponification is complete and the mass becomes uniformly solid. The product is then mixed with a mineral "train" oil in suitable proportions.

Gums and mucilaginous substances are also used in preparing solidified oils. Thus the Arabal Manufacturing Co. (Fr. Pat. 404,959, June 23, 1909) employ a viscous vegetable material prepared by steeping marine algae, etc., in water and adding a small quantity of an aldehyde, such as formaldehyde, or, instead of the algae, nitrogenous compounds of the algae, such as "ammonium tangate," may be employed. The gelatinous products thus prepared are intimately mixed with oils, fats, etc., for the production of lubricating compounds.

The following are analyses of solidified oils by Heller:

Analyses of Solidified Oils (Heller)

Sample No.	1.	2.	3.	4.	5.	6.	7.	8.	9.
Moisture	5.4	5.8	4.0	8.2	1.5	3.5	7.9	2.9	2.0
Neutral fat	10.2	18.8	25.1	20.1	—	4.0	28.6	25.4	—
Fatty anhydride	13.2	16.4	8.2	10.3	9.6	11.8	9.0	10.3	8.5
Mineral oil	68.5	58.5	63.0	60.0	84.5	74.7	55.1	58.7	50.0
Rosin oil	—	—	—	—	—	—	—	—	40.0
Lime	1.9	1.8	1.0	—	1.6	1.5	—	0.8	1.3
Magnesia	—	—	—	—	—	—	0.9	—	—
Alumina	—	—	—	1.4	—	—	—	—	—
Alkalies	—	—	—	—	—	1.8	—	—	—
	99.2	101.3	101.6	99.7	99.7	99.3	101.4	99.0	101.8

The Fatty anhydride in No. 2 was linoleic, and in No. 4 coconut oil. The Neutral fat in No. 1 was rape oil; No. 2, linseed oil; No. 3, olive oil; Nos. 4, 5, and 6, rape oil; and No. 8, castor oil.

CHAPTER X.

LIQUID LUBRICANTS.

THE liquid lubricants possess many important advantages over the greases, in consequence of which they are preferred for the majority of purposes. Their chief superiority lies in the fact that they do not require such complicated appliances (grease boxes), they begin to act as soon as they are applied, not needing the heat generated by friction to make them sufficiently fluid; besides which the oiling vessels can be of a simple type, even on the axles of vehicles. Finally, they exhibit the valuable property that their consistency is less affected by the temperature of the air than is the case with greases.

The best materials for the preparation of the liquid lubricants are :—

1. Sperm oil.
2. Rape and colza oils.
3. Olive oil.
4. Rosin oil, either alone or in association with lime or certain products of dry distillation (paraffin).
5. Train oil.
6. Neatsfoot oil and bone oil.
7. The so-called mineral oils (solar oil, coal oil).
8. Petroleum and ozokerite.
9. Soap solutions.

Lubricating Oils in General.—Oils taken direct from the press are unsuitable for use as lubricants, and have to be put through a special treatment known as refining.

It will easily be understood that, under the powerful pressure to which the cells enclosing the oil are subjected in the press, not only are the cells ruptured, allowing the oil to escape, but particles of solid vegetable matter—mucilage,

albumin, and other compounds—are expressed with the oil, rendering the latter turbid and slimy, instead of clear and transparent, the presence of these impurities soon resulting in the oil becoming rancid.

One method of clarifying the oil is to store it in tanks for a considerable time, to allow the impurities to settle out. The oil, however, being somewhat viscous, and the solid particles of rather low density, differing little from that of the oil itself, their deposition as a consequence is a very slow process, and is never quite complete, however long the oil is kept in store.

Endeavours to clarify the oil by filtration are also not altogether successful, the oil running through very slowly even at first, whilst the mucilaginous substances present soon clog the pores of the filtering medium and stop the process entirely.

If a permanently efficient filter could be constructed for treating oil it would be extremely useful in the manufacture of lubricating oils. Oil that has been filtered when fresh from the press is perfectly neutral if kept out of contact with air, that is to say, it contains no traces of free fatty acids. This must be regarded as a very great advantage, since the free fatty acids are able to corrode metals seriously and thereby contribute to the rapid wear of the machine parts.

Latterly a number of fatty oils have been obtained by extracting the oil-bearing materials (crushed seeds, etc.) with benzol, carbon disulphide, etc. Oils recovered in this way are, as a rule, free from uncombined fatty acids, and therefore quite suitable for use as lubricants.

Pressed oils have therefore first to be refined, for which purpose many methods have been proposed.

The processes consist in the treatment of the oils either with acids for the destruction of the albuminous and suspended matters, with alkalies for removal of the free fatty acids, or with oxidising agents for bleaching the colouring matters. Many methods have been published but we have confined ourselves to the consideration only of those processes which are in actual use and which have proved particularly suitable for refining lubricating oils. (See pp. 23 to 32.)

CHAPTER XI.

COHESION OILS.

It cannot be disputed that some lubricants, the liquid varieties in particular, are very wasteful in use, so that when there is a large number of axles in constant work, as is the case on railways, for instance, the expense of lubrication becomes very great, though in other respects they may fulfil their purpose adequately.

To remedy this defect and reduce the consumption of lubricant to a minimum, the so-called cohesion oils have been compounded, which are, quantitatively, more economical than any other kind.

As the name implies, these lubricants are distinguished by possessing a lower degree of fluidity than the ordinary liquid grades.

Opinions vary as to the efficiency of these cohesion oils, for while some large consumers of lubricants declare that they prefer them to refined olive or rape oil, others do not give such a favourable report, but complain that the cohesion oils make the bearings and lubricating appliances very dirty, and that the oils deposit such a large amount of sediment as to prevent efficient lubrication.

The author's opinion, from his own experience in the matter, is that an oil exhibiting these last-named properties must be classed as bad. Some makers, with a view to improving their products as much as possible, have continued to increase the cohesive properties until some of the oils placed on the market have been almost too viscous to pour out of the can, and would draw out into threads like partly set glue.

Cohesion oils containing such an immoderate proportion of constituents producing viscosity, will readily deposit these

as a sediment on standing, the resulting thick mass being unsuitable for lubrication.

Certain oils of the class in question now being put on the market are stated to have been prepared by secret processes. The chemical examination of a number of these oils, however, shows that certain makers add colouring or scenting ingredients (sometimes both) which are quite inert as regards lubricating properties, being used for the sole purpose of masking the properties of the other components and preventing their detection.

Nevertheless, despite these intentional deceptions, the skilled chemist is able to analyse these products; and the various experiments performed on cohesion oils of English, German, and American origin, clearly show that they are all made from the same fundamental materials.

Without exception, the basis of the cohesion oils is a more or less viscous oil, crude rape oil being most frequently used, train oil more rarely, whilst occasionally tallow, palm oil, neatsfoot oil, or other solid fat is added to reduce the fluidity.

In addition to the fats, these oils all contain variable quantities of rosin oil, the amount ranging within wide limits; and experiments have shown that from 8 to 20 per cent. of rosin oil can be used.

The substance employed for increasing the viscosity is ordinary American pine rosin; and the larger the amount added, the higher the cohesion of the oil. The additions range from 8 to 15 per cent. of the weight of the oil; but it is inadvisable to exceed this latter limit, especially if the lubricant is to be used at low temperatures.

The preparation of cohesion oils is usually a simple matter. The rape oil is gently warmed in a pan and mixed, with the necessary quantity of solid fats (palm oil, tallow, etc.) when these are used. The rosin oil is heated, almost to ebullition, in a second pan, precautions being taken to prevent ignition of the contents, and the rosin, broken into small pieces, is added by degrees, one portion being allowed to dissolve completely before another is added. Solution must be assisted by stirring, to prevent any rosin adhering to the bottom of the pan and burning there.

When the rosin is completely dissolved, which requires but little time, the solution is ladled into the pan containing the oil. The latter is kept constantly stirred; and when all the rosin solution is in, the fire is put out, and the mass is stirred until it begins to thicken.

The following recipes give the composition of two cohesion oils, No. 1 being the thicker, and therefore suitable for quick-running, heavily laden axles, whilst No. 2 is suitable for lighter ones.

Under similar conditions, No. 1 may be used in summer and No. 2 in winter.

Cohesion Oils:—

	1.	2.
Raw rape oil	95	96
Refined tallow	5	4
Rosin oil	12	4
American pine rosin	12	8

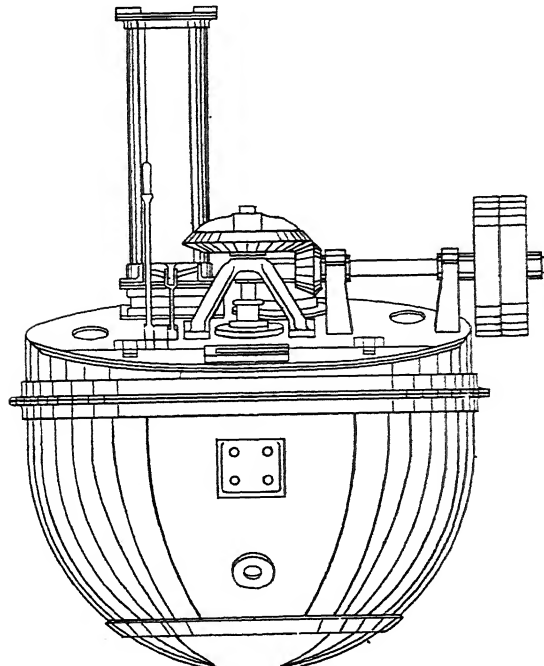


FIG. 12A.—Jacketed Pan for Mixing Lubricating Greases
(W. McNeill & Son, St. Helens).

CHAPTER XII.

LUBRICANTS COMPOSED OF FAT OR OIL AND ROSIN OIL.

ROSIN oil is miscible with solid and liquid fats in all proportions, the products exhibiting properties corresponding to those of the components of the mixture.

Rosin Oil and Train Oil Lubricant :—

Rosin oil	100
Refined train oil	50

Since this mixture deposits a sediment after standing for some time, it is important that it should not be used as soon as made, but should be stored in vats or casks for a time.

Solar Oil Lubricant :—

Solar oil	80
Refined rape oil	20

This lubricating oil is particularly suitable for brass and bronze machine parts, as it does not corrode these metals to more than an inappreciable extent.

Thick Oil Lubricants :—

	No. 1. <i>For Winter Use.</i>	No. 2. <i>For Summer Use.</i>
Tallow	35	60
Rosin oil	10	8
Rape oil or olive oil	65	40

Patent Rosin Oil Axle Grease.—This lubricant, which is of a special character, both in its composition and method of preparation, consists of a combination of the acids formed during the dry distillation of rosin, with lime and the volatile oils (rosin oil) also formed during that process.

To obtain a rosin oil suitable for this purpose, all the liquid distillates passing over between 170° and 185° C. are collected separately, only the heavier fractions being regarded as rosin oil, whilst the above-named lighter fractions are utilised direct in place of oil of turpentine.

The distillation of the rosin is preferably conducted in an iron still resembling the retorts used in gasworks. For working on a small scale, the ordinary iron or copper stills may be used.

The primary ingredient for making axle grease of these rosin oils is slaked lime. This is prepared by pouring water over quicklime until it ceases to take up any more. The lime soon begins to grow hot, cracks, swells up, and finally crumbles away into a delicate powder, namely, calcium hydrate, or slaked lime.

This product is stirred up with just sufficient water to form a fairly thick milky liquid, which is then strained through a very fine wire gauze sieve, in order to remove small stones, grains of sand, and other solid bodies accidentally present in the lime.

The vat into which the milk of lime is strained must be fitted with a number of tap holes at short vertical intervals. In proportion as the liquid in the vat clarifies it is drawn off, until finally there is nothing left but a very fine, white pulp of milk of lime.

Into this the rosin oil is poured in the form of a thin stream, the lime being kept stirred all the while. The mass soon thickens owing to the separation of water, whereupon the supply of rosin oil is stopped, and the operation completed by stirring the mass until perfectly uniform.

The proportion of lime required varies, but 20 to 25 per cent. of the weight of the rosin oil is usually sufficient.

The colour of this grease is pale to dark yellow, according to the quality of the rosin oil used: it is semi-transparent, and possesses several advantageous properties. When the grease is made on a large scale, the rosin distilled on the premises, and the stirring effected by some cheap form of power, the price of the product works out so low that it is able to compete with any other form of grease.

The second advantage offered is that of general applicability. The grease may be used equally well in summer and at fairly low winter temperatures, its consistency varying only slightly with changes of temperature. Its firmness renders the use of any special grease-holder unnecessary;

and for ordinary waggons it is sufficient to smear the axles well with the grease to keep them effectually lubricated for a considerable time.

Rosin Greases (Jean) :—

	1. Per Cent.	2. Per Cent.	3. Per Cent.
Water	5.88	4.96	5.65
Rosin oil	62.40	63.20	58.54
Mineral matter	32.32	31.84	32.82
Sulphate of lime	28.80	28.20	32.00
Carbonate of lime	3.19	3.41	1.36
Insoluble	0.22	0.23	0.28

Paraffin Oil Grease.—Towards the close of the distillation of crude petroleum certain thick oils, known as paraffin oils, come over. These products are admirably suited for the preparation of lubricants for heavily loaded axles. These paraffin oils are easily mixed with fatty oils, except castor, all that is necessary being to run the fatty oil (generally rape oil) and the paraffin oil together, and then mix them by continued stirring. When these greases are to be used on machines that are exposed to changes of temperature, it must be borne in mind that the consistency of the grease increases considerably at low temperatures, and therefore the proportion of paraffin oil must be greatly reduced for winter use. The two following recipes are for summer and winter grease respectively :—

Paraffin Oil Greases :—

	Summer Grease.	Winter Grease.
Paraffin oil	10	6
Refined rape oil	90	94

It is self-evident that these recipes can also be modified to furnish greases suitable for medium temperatures, *i.e.* spring and autumn use, all that is necessary being to alter the proportion of rape oil accordingly.

These paraffin oil greases, which have hitherto been insufficiently appreciated, form excellent lubricants for both axles and machinery, and can be produced cheaply wherever paraffin oil is easily obtainable. In addition to perfect lubri-

cation, they have the advantage of not corroding the machine parts.

Paraffin and Petroleum Jelly Grease.—Pure white paraffin and petroleum jelly can be mixed in any proportion by melting them together, furnishing greases ranging in consistency from that of soft butter to thick salve, according to the proportions of the two constituents. Being perfectly free from acid, they are admirably suited for fine machinery and axles, running at both high and low speed.

CHAPTER XIII.

LUBRICANTS FOR SPECIAL PURPOSES.

Greases for Quick-Running Axles :

1.	Soap	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
	Rapeseed oil	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
	Water	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
	Powdered talc	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
2.	Brown ozokerite	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
	Petroleum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4

In the case of No. 1 the ingredients are mixed by boiling and stirring them together, whilst for No. 2, melting together is sufficient.

Piston-Rod Grease :—

Paraffin	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Powdered talc	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4

These are stirred together whilst hot, wicks are then dipped in the mixture, and are afterwards pressed into position in the piston-rod gland. This lubricant will grease a piston-rod for 8 to 14 days with one application.

Cog-Wheel Grease. Any convenient pasty lubricant is melted and stirred up with 5 per cent. by weight of finely ground and levigated powdered glass. In a short time this lubricant polishes the cog-wheel teeth perfectly smooth and even.

Driving-Belt Grease :

Linseed oil	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	45
Litharge	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
Water	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20

These three substances are boiled together until the mass has assumed the consistency of plaster, which is thinned to about the same degree of fluidity as varnish, by addition of oil of turpentine while slightly warm.

Belting Grease :—

Linseed oil	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
Litharge	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4

The linseed oil and litharge are boiled together with water, until a sample sets to the consistency of plaster, the mixture being then thinned with oil of turpentine while still warm.

Caoutchouc Grease for Driving Belts:—

I. Five hundred parts by weight of caoutchouc are dissolved in an equal weight of oil of turpentine at 122° F., and mixed with 500 parts of colophony and 500 of yellow wax.

II. One and a half parts of fish oil are melted with 500 parts of tallow, and the mixture is stirred with the solution No. 1 until the mass sets. The grease is laid on the belts with a brush, in the vicinity of a hot stove.

Belgian Cart Grease:—

Lime, slaked to powder	100
Tar oil	300
Paraffin oil	800
Rosin oil	300
Strong soda lye	12
Powdered soapstone	800

The dry-slaked lime and the lye are placed in a pan, in which they are stirred with the rosin oil until the whole mass is white. This being gently warmed, the tar oil is stirred in, followed by the paraffin oil, the soapstone being finally added. The finished composition is stirred until homogeneous.

Under the same name as the above, a number of different preparations have been placed on the market. Their chief constituents, however, are those just given, the colour (red, brown, blue, or black) being the chief point of difference. The red colour is imparted by colcothar (*caput mortuum*), brown by lamp black, blue by ultramarine or Prussian blue, and black by a larger proportion of lamp black. In some recipes powdered soapstone is replaced by ground heavy spar, which is distinctly objectionable; being a very hard, crystalline substance, it is capable of abrading and wearing out the machine parts it is used to lubricate.

English Patent Axle Grease.—This term is applied to a whole series of compositions, consisting mainly of a kind of lime soap with variable proportions of rosin oil and coal-tar oil, the product being coloured yellow, brown, blue, etc.

The lime soap, or "basis," is usually prepared by stirring

and heating train oil with slaked lime until the two become united to form a thick liquid. The general proportion of the ingredients is 7 parts of oil to 5 of lime; but the exact amount of the latter varies according to the nature of the train oil. The correct amount is reached when the product in the pan exhibits a syrupy consistency after being boiled for about an hour.

These patent greases are usually prepared on a large scale, the ingredients being mixed in large vats fitted with stirrers driven by power. Stirring must be continued until a sample taken from the mixture sets to a homogeneous mass.

White Patent Grease:

Basis	.	.	.	.	.	.	.	.	.	100
Rosin oil	.	.	.	.	.	.	.	.	.	100

Blue Patent Grease:

Basis	.	.	.	.	.	.	.	.	.	100
Rosin oil	.	.	.	.	.	.	.	.	.	125
Coal tar oil	.	.	.	.	.	.	.	.	.	15.25

These proportions may be varied according to the consistency desired. The grease is coloured blue with ultramarine or Prussian blue. The brown and black greases are made in the same way, the only difference between the various kinds being in the quantity of rosin oil and the kind of colouring matter used.

Soap and Mineral Oil Lubricants. A special group of lubricants is formed by compounding soap and mineral oils. When petroleum is heated with 2 to 3 per cent. of soap to the boiling point of water for a short time, with continued stirring, the whole sets to a buttery mass. A similar result is obtained by boiling rosin-and-lime soap with rosin oil in a similar manner.

The rosin-and-lime soap is prepared by treating quicklime with sufficient water to slake it to powder, which is then thinned down with water to form a milky liquid which is heated to boiling. Rosin, in the proportion of about $1\frac{1}{2}$ times the weight of the lime, is stirred into the boiling liquid, the whole being then left to cool, whereupon the supernatant liquid is poured off and the soap dried.

To make the lubricant, rosin oil or heavy tar oil is heated

and mixed with about 2 to 5 per cent. of the dry lime soap, the whole being boiled and sampled from time to time, the sample being cooled quickly and examined. If too little of the lime soap has been added, the sample will be too soft and more soap must be added; but if the sample should prove too hard, then the proper consistency is obtained by adding rosin oil or mineral oil. Since the various rosin oils and mineral oils behave differently in this respect, no exact recipes can be given, therefore the amount of lime soap required for a given quantity of rosin oil must be determined by trial in each case.

Coll's Patent Lubricating Oil.—This preparation consists of rosin oil which has been boiled together with a quantity of slaked lime insufficient for complete saponification. Hence the composition is really a rosin oil and lime soap mixed with an excess of rosin oil. Being perfectly free from acid, it can be recommended as a lubricant.

American Machine Oils and Solid Greases.—A number of these products have been found, on examination, to possess the following composition :—

1. Oleic acid	90
Petroleum	10
2. Oleic acid	100
Glycerine	50
3. Oleic acid	100
Guaiacum oil	20
4. Glycerine	100
Petroleum	10
5. Glycerine	100
Olive oil	50
6. Gambier fat	100
Coal tar	30

Turbine Oils :—

	1.	2.	3.	4.
Yellow rosin oil	200	200	40	40
Blue rosin oil	—	33	—	—
Olive oil	1	—	40	—
Rapeseed oil	—	33	—	—
Olein	—	—	60	—
Cottonseed oil	—	—	—	30
Paraffin oil	—	—	—	30

These oils are suitable for all quick-running shafts or axles under light loads.

Rope Grease for Wire Ropeways:—

Tar	.	.	.	.	.	.	.	.	.	100
Brewer's pitch	.	.	.	.	.	.	.	.	.	100
Colophony	.	.	.	.	.	.	.	.	.	25
Train oil	.	.	.	.	.	.	.	.	.	10-25

These are melted together and stirred until the mass is cold.

Schuckart's Patent Belting Grease.—This fat, which is intended to prevent leather belts slipping on the pulleys, consists of castor oil containing an addition of up to 10 per cent. of tallow according to the temperature.

Drechsler's Patent Graphite Lubricating Powder.—Finely powdered graphite is mixed to a paste with egg albumin, then heated to about 160° F. (to coagulate the albumin) and reduced to powder. This preparation is no improvement on graphite and tallow mixtures, which are cheaper.

CHAPTER XIV.

MINERAL LUBRICATING OILS.

THE name "mineral lubricating oil" is applied to a series of products obtained in very large quantities in the refining of crude petroleum and the distillation of coal tar. Since these oils are unsuitable for lighting purposes, owing to the dim, smoky flame they yield when burned in lamps, and become more and more consistent as their density increases, they may, in view of this latter property, be regarded as true universal lubricants, since they can be manufactured in all degrees of consistency from very thin to extremely viscous oils. They possess, also, the property of absorbing considerable quantities of paraffin, and of becoming thicker in proportion to the amount taken up.

Attention is specially directed to these oils because they are easily prepared, and can be produced in large quantities in petroleum refineries and tar distilleries. The introduction of these lubricants has had a marked influence on the trade, and they now constitute by far the most important oils for the purpose.

Owing to their freedom from acids and on account of their cheapness, the mineral oils are admirably adapted for the preparation of lubricants. In making a choice, selection should fall on the heaviest oils, which on account of their high density are of little or no use for burning.

In America the method adopted is to subject the crude petroleum to fractional distillation, and as soon as the distillate has reached the required density, the fractions subsequently passing over are collected and sold as lubricating oil. Properly prepared lubricating oils of this kind are almost entirely inodorous and pale in colour. They may be used either alone—as fine machine oil—or mixed with rosin and paraffin.

Vulcan Oil is one of the mineral lubricating oils, and is obtained in the distillation of Virginia petroleum. It has the specific gravity 0·870 to 0·890, and is purified by treatment with sulphuric acid.

Globe Oil, etc.—The mineral lubricating oils largely imported from America under the names *Globe oil*, *Eagle oil*, *Phoenix oil*, etc., have properties closely resembling those of *Vulcan oil*, and, like that oil, are obtained by the fractional distillation of crude petroleum.

Thick Mineral Lubricating Oils (Greases).—These oils are prepared by boiling together milk of lime, a vegetable oil and a mineral oil, until a homogeneous salve-like mass is obtained. During the operation a lime soap is formed, which dissolves in the oils; the larger the quantity of this soap, the higher is the melting point of the grease. On account of this high melting point and the viscosity of the mass when melted, these greases are specially suitable for high-pressure steam engines. The preparations known as *Patrick's*, *Reisert's*, *Tovote's greases*, etc., belong to this class.

Recipes for Mineral Greases :—

	1.	2.	3.	4.	5.	6.
Mineral oil .	100	100	100	100	100	100
Linseed oil .	30	30	25	—	75	—
Ozokerite oil .	20	20	35	—	—	20
Rape oil .	—	—	—	40	50	30
Coconut oil .	—	—	—	10	—	—
Rosin oil .	—	—	—	—	100	—
Lime .	9	5	—	10	25	15
Magnesia .	—	4	—	—	—	—

"Vaseline."—Under this proprietary trade name, or as *"Paravaseline,"* are placed on the market (in the first place from America) lubricants that admirably fulfil their purpose, since, being free from acids, they do not corrode the metallic parts of the machinery. They consist exclusively of the by-products obtained in the distillation of Pennsylvania crude petroleum. In this process there remain as residuum in the stills semi-solid masses consisting of various solid and liquid hydrocarbons of very high boiling point, which, after refining, are capable of direct utilisation as lubricants.

"*Paravaseline*."—Lubricants of greater fluidity can be obtained by mixing "Vaseline" with petroleum; and conversely, thicker lubricants can be prepared by the addition of crude paraffin or ozokerite. "*Paravaseline*," for instance, is compounded of "Vaseline" and paraffin. Generally these lubricants are coloured by means of cheap colouring matters: colcothar for red, umber for brown, etc.

Soap and Petroleum Jelly Greases.—Crude petroleum jelly mixed with ordinary or rosin soap furnishes a very good railway grease, green to brown in colour. 6 to 8 parts of crude petroleum jelly are melted together with 1 part of tallow and 1 of colophony, $1\frac{1}{2}$ parts of soda lye (20° Bé.) being poured in in the form of a thin stream, and the whole stirred continuously until the mass begins to get viscous, whereupon it is poured into cans, drums, etc., for sending out.

Lanolin Lubricant.—In scouring sheep's wool a product known as wool fat, wool yolk, or suint, is obtained, and this in turn furnishes lanolin or wool oil. Lanolin, when quite pure, is a soft mass of fatty character, but is not a fat, and therefore never turns rancid, so that it forms an excellent lubricant. It is particularly adapted for axle grease, only the crude lanolin, of course, being used for this purpose. The method of preparation adopted consists in heating some vegetable oil with milk of lime and crude petroleum jelly, until a homogeneous mass is obtained, melted lanolin being then added in a thin stream and stirred with the rest until the product has attained the consistency of soft salve. The mass may be stiffened to any desired extent by the addition of ground soapstone, clay, or infusorial earth.

Lanolin Axle Greases:—

	1.	2.
Rape oil	10	—
Linseed oil	—	10
Quicklime	5	5
Water	20	20
Crude petroleum jelly	500	600
Crude lanolin	40	40

with clay, soapstone, or infusorial earth in the proportion of 10 to 25 per cent. of the whole mass.

CHAPTER XV.

CYLINDER OILS.

CYLINDER oils are a special class of lubricating oils having great "body," high boiling point, and little tendency to volatilise. They consist either solely of the higher boiling point fractions of petroleum or the same compounded with hog fat, neatsfoot oil, or other saponifiable oil in the proportion of about 15 per cent.

In the preparation of cylinder oils from crude petroleum, the latter is heated in stills with open fire and high pressure steam till all the lighter portions, naphtha and kerosene, have passed over and a considerable proportion also of the oils which are usually employed for lubricating purposes. The residue in the still after settlement forms "steam refined cylinder oil," which is dark in colour and can be obtained at a very moderate price. By continued further heating higher grades of cylinder oil are obtained, which are purified by careful filtration. The pale cylinder oils are prepared by filtering through animal charcoal.

Not all crude oils are suitable for the manufacture of cylinder lubricants, and great care is required in the process to prevent "cracking" or the deposition of tar, etc. From a suitable oil the yield is but small, thus the following may be taken as the average times of heating and the yields:

Ordinary cylinder oils, 24 hours	15 per cent. on the crude.
High flash cylinder oils, 36 hours	" " " "
Very high flash cylinder oils, 48 to 60 hours	" " " "

From the examination of a large number of cylinder lubricating oils, Wells (*see footnote*) chose out twelve which were regarded as typical of the usual varieties, and these were fully examined. The specific gravities varied between 0.887

¹ "Cylinder Oil and Cylinder Lubrication," by H. M. Wells, *The Engineer*, July 17 to August 14, 1903.

and 0.922, vaporising temperature 154° to 450° F., flash point, closed test 246° to 558° F., flash point, open test 288° to 570° F. Loss in weight on heating to 360° F. at atmospheric pressure 80 hours 0 to 12 per cent., ditto at 140 hours 2.6 to 17 per cent. Viscosities at 212° F. (100° C.) 122 to 312 (water at 70° F. = 32) and viscosities at 600° F. (315° C.) 26 to 43. The most interesting results are the viscosities which are seen to fall rapidly as the temperature rises, and at 600° F. they have almost a constant value which is extremely low and in fact approximating to that of water. At ordinary temperatures the oils are almost too thick to flow.

According to A. Cormorant¹ lubricating oils intended for use in engines working with superheated steam should have as near as possible the following characters:— Specific gravity 0.90; fluidity at 35° C., 12° to 15° (Barbey); at 100° C., 100° to 150° (Barbey); viscosity at 50° C. 50 to 60 and at 100° C. 6 in Engler's viscometer; ignition point, close test, 300° to 330° C. For engines working with saturated steam the figures should be, specific gravity, 0.88; fluidity at 35° C. 40° to 50° and at 100° C. 150° to 250°; viscosity at 50° C. 30 and at 100° C. 35.

In the measurement of fluidity Barbey's "ixometer" is employed. This consists of a tube 5 mm. diameter and 200 mm. long in which is fitted a rod 4 mm. diameter centred exactly in the same axis as the tube, thus leaving a capillary space between the rod and the tube through which the oil is made to flow. The fluidity is measured by the number of c.c.'s of oil which pass in one hour at a definite temperature and under a constant pressure of 100 mm. The apparatus is standardised with fresh cold-drawn castor oil, 100 c.c.'s of which pass in that time = 100° (Barbey).

Oils which lose a considerable amount on heating, say to 360° F., are unsuitable for use in cylinder lubrication, because not only is this portion given off by evaporation in the cylinder and carried away by the steam, but it passes with the condense water into the boiler where it is distinctly detrimental and in fact dangerous.

¹ *Bull. Soc. Ind., Nord de la France*, 1913, **41**, 153-156.

Table giving the density, behaviour in the cold, colour by reflected and transmitted light, flash point and ignition point (open test), and viscosity, of a series of heavy mineral oil (Kunkler).

Designation and Origin of Oil.	Density.	Behaviour in the Cold. °C.	Colour.		Flash Point, Open Vessel. °C.	Ignition Point, Open Vessel. °C.	Viscosity. (W ater at 20°C. = 1.)	
			By Transmitted Light.	By Reflected Light.			50° C.	150° C.
GERMAN :— HAYOVER : Dark machine	0.928 0.918 0.912	- 9 solid - 10 fluid - 10 "	Black-brown " "	Greenish " "	155 164 162	193 193 193	15.48 8.65 3.84	— — —
ATLAGE : Dark machine	0.924 0.885	- 2 solid 0 "	Brownish-green Pale yellow	" Bluish-green	152 110	195 145	4.35 1.61	— —
SAXONY : Spindle Miscible	0.900 0.882	- 7 " - 5 "	" Yellowish-red	Greenish Bluish-green	126 98	148 112	1.30 1.09	— —
GALICIA :— Spindle Pale machine	0.904 0.914	- 4 " - 2 "	Yellow Reddish-yellow	Greenish "	148 165	183 205	3.4 4.8	— —
" cylinder	0.932	0 "	Deep red	Bluish-black	182	230	7.2	—
RUSSIA :— Spindle	0.885 0.895	- 10 fluid - 10 "	Pale yellow "	Greenish-blue "	150 163	170 190	2.0 3.40	— —
" Pale machine	0.909	- 10 "	"Yellow"	"	197	234	6.60	—
" cylinder	0.916	- 10 "	Reddish-yellow	"	215	265	—	1.42
Dark	0.920	- 8 solid	Blackish-brown	Greenish	210	235	—	1.53
" machine	0.910	- 10 fluid	"	"	150	186	6.90	—
" "	0.916	- 10 "	"	"	180	220	1.60	—
AMERICA :— Spindle	0.885	- 2 solid	Pale yellow	Bluish-green	174	202	1.80	—
" Pale machine	0.906	- 1 "	"	"	185	212	2.55	—
" cylinder	0.892	+ 5 "	" brown	Dark brown	232	311	—	1.68
" " "	0.886	+ 5 "	Reddish-yellow	Greenish	233	330	—	1.78
" Dark cylinder	0.898	+ 3 "	Blackish-brown	"	230	315	—	1.76
" " "	0.906	+ 3 "	Brown	"	235	344	—	2.01
" " machine	0.834	- 3 "	Black-brown	"	188	222	5.10	—

The deposits which occur in the cylinders of steam engines have been examined by W. Worrall and J. E. Southcombe,¹ who found them to consist of an asphaltic or pitchy substance mixed with magnetic oxide of iron, the latter probably carried over from the boiler by the current of steam. A sample of this material consisted of 13.5 per cent. of organic matter and 86.5 per cent. of magnetic oxide. The organic matter was found to be composed of resinous or bituminous matter formed by polymerisation of certain constituents of the oil and fatty acids formed by oxidation which were in part combined with the ferrous iron. Similar deposits were found to be formed when oils were heated in an iron cylinder in contact with finely divided copper when moist air was passed through them.²

No relationship could be traced between the iodine value of oils and their liability to deposit this bituminous material.

¹ *Jour. Soc. Chem. Indt.*, 1908, 309.

² J. E. Southcombe, *Jour. Soc. Chem. Indt.*, 1911, 261.

CHAPTER XVI.

THE "GERM PROCESS" OF LUBRICATION OF MESSRS. WELLS AND SOUTHCORBE.

THE presence of free fatty acids in lubricating oils has always been regarded as detrimental from the point of view of their liability to corrode the bearings, but until recently, the effect of free fatty acids on the lubricating value of an oil had not received very much attention. H. M. Wells and J. E. Southcombe state as the result of their experience that "compound lubricating oils" owe their superiority over pure mineral oils to the fact that a small proportion of free fatty acid is present in the saponifiable oil or is generated in it by hydrolysis, and they propose to improve the quality of mineral oils for lubricating purposes by adding 1 or 2 per cent. of a fatty acid, such improvement being claimed in their patent.¹ They remark that acids having low molecular weights, for instance butyric, cinnamic and naphthenic acids yield non-emulsifiable oils, while on the other hand acids with high molecular weights, *e.g.* those of rape oil, wool grease or whale oil, produce emulsifiable oils, the latter being suitable for marine lubrication.

In their paper on "The Theory and Practice of Lubrication," Messrs. Wells and Southcombe point out that "oiliness" and viscosity are not synonymous terms since there are very viscous liquids which do not lubricate, also it is probable that no pure substance has a high lubricating value.

By employing the "drop pipette," which measures the number of drops given by a definite quantity of oil, they found that the surface tension of animal and vegetable oils is much lower than that of mineral oils, their results being as follows:—

¹ Eng. Pat. 130,377, May 2, 1913.

solid surfaces more easily, and it should therefore help in lubrication, which was found to be the case as indicated by the above experiments.

A series of determinations by L. Archbutt on a Thurston machine under a load of 270 lb. per square inch and a peripheral speed of 7 feet per minute clearly showed the beneficial effect of fatty acids in reducing friction. The results are as follows:—

	Friction Coefficient.
Pure mineral oil	0.0047
" " " with 1 per cent. rape oil fatty acids	0.0033
Mineral oil	0.0078
Neutral rape oil	0.0050
Acid rape oil (2.4 per cent. fatty acids)	0.0045
Mineral oil.	0.0078

	Mineral Oil.	Rape Oil Fatty Acids.	Friction Coefficient.
1	100.0	nil	0.0066
2	99.5	0.5	0.0049
3	99.0	1.0	0.0045
4	98.0	2.0	0.0042
5	100.0	nil	0.0066

	Mineral Oil.	Neutral Rape Oil.	Friction Coefficient.
1	100	nil	0.0066
2	90	10	0.0065
3	80	20	0.0062
4	60	40	0.0053
5	40	60	0.0047
6	20	80	0.0041
7	nil	100	0.0043
8	100	nil	0.0062

It is evident from these experiments that 1 per cent. of fatty acids reduces the friction coefficient equivalent to that effected by 60 per cent. of neutral oil.

CHAPTER XVII.

CLOCKMAKERS' AND SEWING MACHINE OILS.

LUBRICANTS for clocks and delicately constructed machinery in general are usually prepared from very carefully refined rape oil, or preferably fine olive oil. To remove the last traces of acid from the oil, it is shaken up with 1 per cent. by weight of caustic soda, this being repeated several times daily for two or three days. A large volume of water is then added, and the supernatant oil, which is now quite free from acid, is poured off.

It still, however, contains colouring matters and certain other constituents inimical to lubrication: and in order to remove these the oil is shaken up with strong alcohol, which dissolves them out.

For this purpose, 10 parts by volume of the oil are placed in a clear glass bottle together with 2 parts of 90 per cent. alcohol. The bottle is well corked, and shaken up so as to thoroughly mix the oil and spirit. The bottle is set out in the sun, shaking being repeated several times each day. At the end of about three weeks—though in bright summer weather, ten to fourteen days often suffice—the oil will be water-white, the supernatant layer of spirit having assumed a strong yellow tinge due to the colouring matter absorbed from the oil.

The purified oil is syphoned off and filled at once into small, tightly corked glass bottles, which should be kept in a cool dark place. The spirit can be recovered, by careful distillation, in a perfectly colourless condition and used again.

According to the author's experiments, the best oil for

clocks is finest olive oil or freshly pressed oil of sweet almonds, bleached with spirit as above, and either used alone or mixed together in equal parts.

Fatty Oil for Clocks.—For oiling clocks the cost of the oil is a relatively unimportant consideration, experience showing that clockmakers and makers of other delicate kinds of machinery will readily pay very high prices for a lubricating oil that will meet their requirements. Lubricants for this purpose must, first of all, have no chemical action on metals, and must not thicken or "gum" in course of time.

As the result of many experiments, the author is convinced that there are only two substances really suitable for the purpose in question, namely, olive oil and pure bone oil. Oil of ben, however, has recently been recommended for the purpose.

Olive Oil for Clockmakers' Use.—To prepare this lubricant an olive oil must be taken that has been refined by the sulphuric acid method already described, and afterwards shaken up with about 2 per cent. of weak soda lye to ensure the complete elimination of the final traces of free acid. The oil and lye are left in contact for several days after a thorough shaking, the oil floating on the surface being then drawn off and bleached with spirit as described above.

Like all other fine lubricating oils, the olive oil so treated must be filled into small bottles, which should then be tightly corked and stored with care.

Bone Oil for Clockmakers' Use.—Bone oil is one of the best lubricants for clocks and other delicate machinery. It is especially useful for turret clocks, owing to its valuable property of remaining perfectly fluid, even at very low temperatures, whilst all other oils set, or at least thicken considerably, at or about the freezing point of water.

To refine bone oil for the purpose in question, the oil, after a preliminary refining process, is exposed to a low temperature, approaching the freezing point of water, and not higher than 35° F.

At the end of several hours, under these conditions, the bone oil will have deposited a solid mass of fat at the bottom of the vessel, and the supernatant liquid portion may then be poured

off. This method of refining bone oil is easily performed in winter; but in summer the operation has to be somewhat modified. With this object, the oil is placed in a vessel, which is then immersed in cold spring water containing lumps of ice, fresh portions of the latter being added in order to keep the temperature near the freezing point for several hours. The vessel containing the oil may then be taken out and the oil poured away from the solid fat.

A still finer product, constituting the best of all lubricating oils, is obtained by treating bone oil in the following manner: The oil to be refined is placed in a flask large enough to hold three times the quantity. Water-white benzol is poured on to the oil in small quantities at a time, and after closing the flask the contents are shaken up until the benzol has entirely disappeared. By repeating this operation several times a complete solution of the fat in benzol will be obtained, this being shown by the fact that the contents of the flask will no longer separate into two layers when left to stand.

The flask is next exposed to a low temperature, as described above, for several hours, whereupon a deposit of solid fat will separate, the quantity of which will be larger in proportion as the cooling temperature is lower. The contents of the flask are then poured into a second flask, through a funnel containing a plug of cottonwool which retains the solid matter and allows the liquid portion to pass through. The resulting clear solution of bone oil in benzol is afterwards placed in a small retort, connected with a properly cooled receiver and heated by means of a water bath. The benzol distils over, leaving the refined bone oil in the retort, whilst the benzol collected in the receiver can be used again.

A suitable distilling apparatus for this purpose is shown in Fig. 13. The benzol solution of bone oil can be introduced into the copper still A by means of a funnel. The cock and tube are then inserted and connected to the worm B by means of a rubber tube. The worm is cooled by a current of cold water which is run into the vessel from the tap D and is syphoned off by the tube E. The fat remains in the still and is filtered through a piece of flannel placed in a funnel. This

portion furnishes an excellent lubricating oil for fine machines, such as sewing machines, that are not exposed to low temperatures.

Fine Machine Oil.—Ten parts of rape oil are warmed along with 5 parts of 90 per cent. spirit until the latter begins to boil, the whole being continuously stirred. When ebullition of the spirit sets in, the heating is discontinued and the liquid is poured into a large flask of clear glass, in which it is exposed to sunlight until thoroughly bleached.

Oil for Lubricating Gas Engine.—Coconut olein 17 parts, mineral oil (specific gravity 0.905) 83 parts.

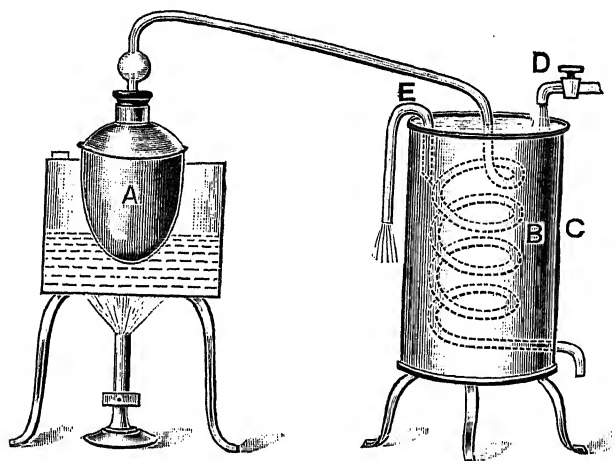


FIG. 13.—Still for purifying bone oil.

Mineral Oil for Clockmakers' Use.—The mineral oil for clockmakers' use is a specially refined heavy tar oil. One hundred parts of ordinary heavy tar oil are treated with 2 parts of bleaching powder, well stirred in, followed by 3 parts of crude hydrochloric acid. The mixture is then vigorously stirred, and set aside for six hours. At the end of this time the oil is poured off from the watery liquid, and repeatedly shaken up with 5 parts of caustic soda lye each time. Finally, the refined oil is filtered through grey blotting paper.

Caoutchouc Lubricant for Sewing Machines :—

Olive oil	.	.	.	.	.	.	.	.	50
Almond oil	.	.	.	.	.	.	.	.	50
Rape oil	.	.	.	.	.	.	.	.	50
Caoutchouc	.	.	.	.	.	.	.	.	2
Carbon disulphide	.	.	.	.	.	.	.	.	4

The caoutchouc is cut into very small pieces placed in a bottle and covered with carbon disulphide in which it is allowed to swell. When this is done it is quickly transferred into a flask containing the oils, this flask being placed in a heated water bath. Whilst the water is being raised to boiling point the mixture is stirred. The swelling of the caoutchouc may require several days.

Care must be taken in heating the mixture of oils and swollen caoutchouc, to avoid inhaling the injurious vapours of carbon disulphide which are given off; and no open light or flame must be allowed in the room in which the operation is performed, these vapours being highly inflammable in admixture with air, and even explosive when ignited.

Mineral Oil for Sewing Machines :—

Petroleum	.	.	.	.	.	.	.	.	100
Water	.	.	.	.	.	.	.	.	10
Bleaching powder	.	.	.	.	.	.	.	.	1

The bleaching powder is dissolved in the water, the solution being filtered and well shaken up with the petroleum. At the end of two hours the oil will have separated from the bleaching powder solution, it is then decanted and shaken with an aqueous solution of caustic potash, from which it is afterwards separated by distillation.

Sewing Machine and Clockmakers' Oil :—

A mixture of—

Olive oil	.	.	.	.	.	.	.	.	3
Almond oil	.	.	.	.	.	.	.	.	2
Rape oil	.	.	.	.	.	.	.	.	1

is treated with alcohol as already described. This mixed lubricant is fairly fluid, and is therefore admirably suited for oiling very fine machine parts.

“Recipes for Motor Cylinder Oils.”—For small gas engines (6 to 20 h.p.) a suitable cylinder oil can be compounded of 94

parts of Russian engine oil I (specific gravity 0·906 to 0·908), and 6 parts of refined rape oil. For the same motors that have been some time in use, the mixture may consist of Russian engine oil I, 80 parts, FFF valve-cylinder oil 10 parts, pale oil 0·900 to 0·907, 8 parts, and palm oil 2 parts. For 1 h.p. motors: Solar red oil 85 parts, steam-refined, extra-filtered cylinder oil, cold-test, 15 parts. Another approved recipe for 15 h.p. motors consists of: Solar red oil 80 parts, FFF valve-cylinder oil 15, best bone oil 5 parts; whilst for a 30 h.p. motor a thicker bone oil should be used, the proportion remaining unchanged" (*Organ für Fett-und Oel-Handel*).

CHAPTER XVIII.

EMULSION LUBRICANTS.

WHEN a fat or oil is shaken with a weak solution of a caustic alkali or an alkaline carbonate and the mixture is allowed to stand for a time, usually some of the oil separates and rises to the surface, but more or less of a milky fluid or emulsion is formed between the oil and the aqueous liquid, this emulsion consisting of innumerable minute globules of oil suspended in a clear fluid.

Oils containing free fatty acids are much more easily emulsified and form more stable emulsions than perfectly neutral oils; in fact, the emulsion is sometimes so perfect that no oil whatever separates. The same result is arrived at when soap is dissolved in the water.

Mineral oils, owing to their neutral characters, are not emulsified by alkalies, but they can be emulsified with soap solutions, the solutions thus formed being now employed on a very large scale under the names of "screwing" and "cutting" compounds.

Prof. F. G. Donnan and H. E. Potts¹ have shown by experiment that in the acetic series of fatty acids, the sodium salts of the acids up to and including caprylic acid had no emulsifying powers, those of pelargonic and capric acids formed very weak emulsions, while the salts of lauric acid and the higher acids were strong emulsifying agents. With the sodium salts of lauric and myristic acids the emulsifying power increased with increasing concentration up to a certain point when emulsification decreased, due, they believed, to the positively charged sodium ions "salting" out or coagulating the negatively charged oil particles above such concentrations. By using Lewis dropping pipette they were also able

¹ *Zeit. Chem. Indst. Koll.*, 1910, 7, 208-214.

to measure the surface tension between the sodium salts of the fatty acids and a hydrocarbon lubricating oil, containing about 0.1 per cent. of fatty acids which they found did not influence the results. These measurements showed that with the acids from acetic to ceanothylic there was very little decrease in surface tension with increasing concentration of the salt, but with caprylic acid and the higher acids the decrease of surface tension was very marked, this decrease being greater in proportion to the molecular weight of the acid.

Sulphonated Oils.—Sulphonated castor oil or Turkey red oil, owing to its property of dissolving or emulsifying with water, is often used as an emulsifying agent.

The following particulars relating to soluble oils are given in the issues of *The Oil and Colour Trades Journal* for November 4, 18, December 2, 1916, and February 24, 1917 :—

Soluble Oils.—The reaction of concentrated sulphuric acid on fatty acids or neutral fats produces sulphonated fatty acids, which, when boiled in water, split up into oxyoleic acid, oxy-stearic acid, and lactones, writes R. Ehrsam, in the *Revue des Produits Chimiques*. In addition, when the original material was a neutral fat, the product contains sulphoglyceric acid, which is decomposed by boiling water into glycerine and sulphuric acid. This action of sulphuric acid on fatty substances is utilised in the manufacture of stearine, Turkey red oil, and other soluble oils. In the last-named case, however, the reaction is not allowed to proceed unchecked, the sulphonation being stopped when it has reached a certain stage. The same process is employed for converting olive oil, pulp oil, and seed oils into sulphonated fatty acids, of which the sulphoricinic acids are the most valuable, since none of the other oils furnishes products so soluble as those from castor oil.

The sulphoricinates, sulpholeates, and Turkey red oils are obtained by washing the sulphonated oils with alkali, and will then dissolve to a clear solution in water. Though formerly restricted to the dyeing and printing of cotton fabrics, these oils now find numerous applications in the arts.

The principal uses of the sulpholeates are in the dyeing, printing, and dressing of cotton fabrics, but they are also

employed in the woollen industry for scouring, softening, milling, and dyeing. A small quantity is also used in the silk industry.

In the oiling (softening) of fibres the sulpholeates offer the advantage of being easily washed out again without the aid of a soap bath, as soluble oils. The sulphoricinates give, with water, limpid fatty solutions, which do not decompose in the presence of the small quantities of lime or magnesia salts in industrial waters; added to dressing and finishing preparations, they advantageously replace glycerine to impart gloss to the fabric and render the latter soft in spite of the starchy matter with which the material has been loaded to impart substance and weight.

When concentrated sulphuric acid is mixed with an oil it destroys the mucilaginous, albuminoid, and other impurities present in the latter, and produces a residue which colours the oil. At the same time, heat is generated which has an adverse influence on the process. Consequently, when the colour of the final product is a matter of consideration, the pale oils from the first pressing are generally employed. On the other hand, the sulphuric acid exerts a catalytic action on the oil by combining with the glyceride and liberates an amount of heat which is the greater in proportion as the reaction takes place at a larger number of points simultaneously in presence of a large excess of the acid reagent. In these circumstances saponification may occur, and a liberation of sulphurous acid injurious to the quality of the resulting product, if the velocity of the reaction should exceed a certain limit by reason of the high temperature. It follows, therefore, that the oil under treatment should be kept in active agitation while the sulphuric acid is being added, in order to distribute the latter as completely as possible throughout the mass. The pouring of the acid should be so arranged that the quantity introduced into the oil may be broken up into minute particles in order to obtain, rapidly, an intimate mixture, the temperature of which will not exceed 104° F.

This result may be accomplished by allowing the sulphuric acid to fall, drop by drop, into the stirred oil, stopping the addition, if necessary, until the temperature of the mixture

has again become normal. In small works, where sulphonated oils are prepared from time to time as required, the operation is performed in a wooden vat mounted on two trestles and provided with a discharge orifice for drawing off the washings. This orifice is closed by a wooden plug fixed on the end of a wooden rod which extends above the top of the vat for the convenience of the operators. An earthenware vessel containing the acid is placed on two beams so as not to obstruct the work whilst allowing the flow of acid to be easily regulated by a tap or leaden tube, 2 to 3 mm. in diameter, closed by a spigot. Rubber gloves should be worn while stirring the oil with a hardwood paddle; but since wood is a bad conductor of heat, there would be no advantage in immersing the vat in a refrigerating mixture. It is, therefore, necessary to stop the flow of sulphuric acid for about an hour, at intervals, in order to prevent the temperature of the mixture from rising above the specified limit. It should be noted that sulphonated oils made in a wooden vat are always dark coloured, in consequence of the action of the acid on the wood. For making small quantities, the vat may, with advantage, be replaced by a vessel of earthenware or porcelain.

Owing to the length of time and amount of trouble entailed by the above method, it is better to add the acid more quickly and to cool the mixture artificially, using a lead-lined sheet iron tank as the mixer; care, however, being taken that the temperature of the mixture does not fall below 68° F., because, owing to its viscosity, castor oil does not readily mix with the acid when cold. The colour of the finished product, however, is paler in proportion as the working temperature approaches the above minimum; nevertheless, in view of the length of time required, the process is generally carried out at about 86° F. In order to distribute the acid in a state of very fine division throughout the oil, the latter is agitated by a blast of compressed air.

In some chemical works a jacketed, flat-bottomed mechanical mixing vessel is employed, made of sheet iron lined with lead, and cooled by a circulation of cold water through the jacket. The mixing apparatus consists of

paddles mounted on a vertical shaft, and may be made of metal faced with lead, or of hardwood parts secured together without glue. These mechanical agitators are run at a speed of about 30 to 40 turns per minute. The temperature of the mixture during the operation is checked by means of a thermometer mounted on the agitator in such a way that the bulb passes through a hole in the top paddle and dips into the oil. The leaden vessel containing the sulphuric acid is located above the mixer, and the tap is set to deliver a stream, about as thick as a match, through a nozzle 3 to 4 mm. in diameter, the rate of feed being from 10 to 24 lb. of acid per hour, according to the quantity of oil treated and the efficiency of the cooling medium.

The proportion of acid (66° B. strength) required for sulphonation usually ranges from 20 to 25 per cent. of the castor oil treated, according as the oil is first or second runnings and to the extent it is desired the process should be accelerated. This proportion increases to 30 and 40 per cent. for sulphonating olein; whereas, for certain Turkey red oils, the castor oil may be sulphonated with 12 to 14 per cent. of acid.

When the oil, the temperature of which should not fall below 68° F., is in the mixer, the stirrers are set going at a speed of 20 to 40 turns per minute, depending on the diameter of the mixer. The lowest paddle should be situated as close as possible to the bottom of the mixer, and arranged so as to direct towards the surface the sulphuric acid which tends to settle down at the bottom during the first stage of the process. The stirrers should be kept at work until the whole of the acid has been intimately mixed with the oil, and the temperature of the mixture falls without the assistance of external means of cooling. This usually occurs about two hours after the introduction of the acid, the flow of which is regulated so as to keep the temperature down below 104° F.—if possible between 86° and 95° F.—this being the most suitable for the process. The resulting sulphuricinate will be the clearer and paler in colour in proportion as the acid is fed in more slowly.

If, for example, 2 cwt of oil be treated, the acid feed is

regulated so that the whole amount will take ten hours to run in, the rate being therefore $4\frac{1}{2}$ to $5\frac{1}{2}$ lb. per hour.

At first the oil remains clear, except where it is turned brown at the seat of contact with the jet of acid; but afterwards the mass assumes a greenish tinge, the oil becoming progressively thicker. No noticeable smell of sulphurous acid is given off, provided the temperature remains normal and the oil is not second runnings contaminated with much chlorophyll and mucilage, which substances are destroyed by the acid and furnish products which colour the oil to an appreciable extent.

Two hours after the introduction of the acid, and when the mixture has decidedly cooled, the stirrers are stopped, and the mass is left at rest for twelve to fourteen hours, with occasional stirring. At the end of that time, about twenty drops of the sulphonated oil are placed in a test tube containing warm alkali water, and after being shaken up are left to stand for a minute. If no separation occurs the oil must be washed, without delay, to eliminate the excess of sulphuric acid.

With this object the sulphuricinic acid, which will be of a dirty brown colour, is drawn off into a lead-lined wooden vat, where it is washed several times—depending on the final product desired—with water at 85° to 95° F. The sulphonated oil being insoluble in acid water, the first washing may be effected with one or two volumes of pure water. The strongly acid washings will settle down in about eight hours, and should then be drawn off. The second washing is effected with a similar quantity of water containing 10 per cent. of common salt, the washings in this case settling down in three to four hours. For the third washing three volumes of water, containing 15 per cent. of salt, are used. In some cases the washing liquors are replaced by a solution of sulphate of soda.

The washed sulphuricinic acid is sufficiently pure for the majority of industrial uses, but for certain products washing should be continued until the final washings no longer exhibit any traces of sulphuric acid. This condition can be ascertained by treating the washings with a solution of

barium chloride, which will precipitate sulphuric acid when present.

The employment of a sodium salt in the washing liquor effects a quicker and more complete separation of the sulpho-fatty acid, which would partially dissolve in pure water. Sulphate of soda is used in preference to the chloride when, for example, the washing is performed at or above 104° F., since both the free sulphuric acid and the sulpho-fatty acid act on common salt with liberation of a certain quantity of hydrochloric acid, which in turn is capable of decomposing the sulpho-fatty acid into fatty acid and free sulphuric acid. This reaction is most liable to occur during the first warm washings, the excess of sulphuric acid being then in a sufficiently concentrated state to react on the sodium chloride. The washing liquor should not be introduced into the vat all at once, but gradually added to the oil, which is kept stirred all the time.

Two cwt. of castor oil treated in this way will yield 240 to 245 lb. of washed sulphonated oil, composed mainly of the sulphuric ether of ricinic acid—a mixture of mono- and poly-ricinic acids.

The product is suitable for general application, though the manufacturing process has to be modified for the production of certain special soluble oils which will be described later.

This group of special products also comprises the oils known as "monopole" and "tetrapole," employed in the textile industry. These differ from the other sulphuric acidates in that their solutions are not rendered turbid by the presence of lime or magnesia. "Monopole" oil is prepared by treating castor or other oils with concentrated sulphuric acid. The sulphonated oils are washed and converted into oxy acids by boiling. These latter are heated to between 104° and 212° F. with a glyceride, and the mixture after cooling is again treated with sulphuric acid. From 25 to 75 per cent. of oxy-fatty acids are taken to 75 to 25 per cent. of oil (glyceride). The product is again washed, and is neutralised according to requirements. "Tetrapole" is a mixture of carbon tetrachloride and a sulphuric acidate soap containing 18 to 27 per

cent. of fatty acids. It, too, will give a limpid solution, even with hard water. Other similar products are met with in commerce.

The soluble oils obtained by neutralising sulphoricinic acid or other sulpho-fatty acids are used as mordants in dyeing, as colour ingredients in printing on textile fabrics, as softening agents in dressing preparations and batching or softening fibres, and as tool lubricants in machine shops. The sulpholeates are sold in the form of aqueous solutions, and as they contain 20 to 30 per cent. of water the proportion of sulpho-fatty acids must be ascertained in order to determine the real value of the articles.

Oils for turkey red and similar purposes are obtained by treating the washed sulpho-fatty acids with a solution of carbonate of soda, or caustic soda, or with ammonia gas, until the product is neutral or only faintly acid. The mass is stirred to render it translucent. The sodium sulphoricinate may clarify before it has become neutral, if too much sulphuric acid has been used on the castor oil, or if the reaction has been too prolonged. When this is the case an addition of alkali subsequent to clarification will transform the sulphoricinic acid into a hard soap. If, on the other hand, the sulphoricinate remains cloudy after having been neutralised with soda the addition of that alkali is suspended, and ammonia is added until the liquid clarifies. Should the turbidity persist insufficient washing is indicated, and in such event sulphate of soda or of ammonia is formed during neutralisation. In order to clarify the liquid the oil must be left at rest at a temperature of 86° to 95° F., to allow these salts to settle down. The soluble dressing oils are usually sulphoricinates of soda, whilst those for dyeing and printing are neutralised with ammonia or a mixture of soda and ammonia. An excess of ammonia increases the solubility of the sulphoricinate without the inconveniences that would arise if an excess of caustic soda were used. Consequently, if the last-named be employed only about four fifths of the acidity should be neutralised, the operation being completed with ammonia. It is preferable to neutralise four fifths of the sulphoricinic acid with soda, and the remaining one-fifth to

make the whole neutral with ammonia. The amount of alkali required for complete neutralisation is about 13 per cent. of ammonia (22° strength), or 5 per cent. of caustic soda in the form of a lye of 20° to 36° B. strength, according to the desired concentration of the oil; for example, 20 to 22 per cent. of 36° lye.

The preparation of concentrated sulphuricinate, for example, one of 80 per cent., presents certain difficulties, the mass becoming gelatinous on the addition of strong alkali, unless introduced in small quantities at a time. On the addition of each successive fraction of alkali the liquid turns milky, but clears again on stirring. When sufficient lye is in, the liquid begins to froth. The alkalinity is tested with litmus after the sulphuricinate has been stirred awhile. The operation is completed by stirring until the liquid is perfectly limpid. The finished product sometimes contains white granules due to defective and partial sulphonation arising from insufficient mixing.

The important point in the preparation of Turkey red oils is to find the precise degree of neutralisation or alkalinity suitable for the application of these fatty mordants. This, however, can easily be ascertained, with a little practice, by the aid of litmus paper.

The textile industry also uses acid sulphuricimates.

When neutralisation is finished the product is dissolved in soft water, the amount of which depends on the selling price and the uses for which the oil is designed. Turkey red oils contain nominally 50, 60, 70 and 80 per cent. of sulphuricinate, though the actual percentage of the 50 per cent. grease is only 39 per cent. of fatty substance, whilst the concentrated grade has only 78 per cent. of fatty acids.

Owing to the tendency of the oil to thicken when concentrated alkali is used for neutralisation, it is preferable to operate with a 20° to 30° lye, provided the strength which the finished oil is intended to have permits.

The best method of preparing sulpholeates is by treating 120 to 200 lb. of oil at a time. The *modus operandi* is as follows: 120 lb., for instance, of the oil are placed in the mixer at a temperature of 59° to 68° F., and 30 lb. of 66° B.

sulphuric acid are run in in the course of four hours, the temperature of the mixture being regulated so as to be as near 86° F. as possible, and not to exceed 104° F. After all the mineral acid has been added the mixer is kept running for two to three hours, after which the charge is left over night in a cool place.

Next day the acid mixture is gradually transferred to a washer containing 11 gallons of water, which is stirred up with the oil so as to produce a homogeneous, viscous, and whitish emulsion, to which another 11 gallons of hot water of condensation are added, with stirring. The mixture is then left in the washer for six hours, being stirred at intervals.

In order to facilitate the separation of the water a solution of $4\frac{1}{2}$ lb. of sulphate of soda in $2\frac{1}{2}$ gallons of water is added, and the well-mixed mass is left over night, the water being drawn off next day. A yield of 71.5 of washed sulphonated oil should be obtained. If this is exceeded a smaller amount of water should be used in the next batch, not only because the concentration of the oil is lowered, but also, and mainly because this acid water increases the consumption of soda. If a sodium sulphoricinate containing 60 per cent. of castor oil be desired, $3\frac{3}{4}$ gallons of water and 2 gallons of 40° B. soda lye (corresponding to $9\frac{1}{2}$ lb. of caustic soda) must be used for neutralising the above product. The washed oil is generally neutralised by mixing with it the necessary quantity of lukewarm water to bring it to the proper strength, or else this water is added with the lye. In any case, the lye should be added to the oil in small quantities, which are intimately mixed by constant stirring. These additions should be made at longer intervals, as the concentration of the lye is higher. As soon as the lye is added the mass turns milky, but afterwards clears, and there is finally obtained a yellow-brown sulphoricinate, which throws up colourless soap bubbles. When this stage is reached the addition of lye should be stopped, although the oil has still a slightly acid reaction and gives a milky solution with water, the solution, however, clearing when a few drops of ammonia or lye are added. If sufficient lye were added to give an alkaline reaction with litmus, a compact, viscous mass, giving

a turbid solution with water, would be obtained. If it be desired to obtain a sulphoricinate which will furnish a limpid solution, the neutralisation should be completed with ammonia. Assuming the operation to have been properly conducted, a yield of 224 lb. (22 gallons) of sulphoricinate will be obtained.

In preparing potassium sulphoricates the same method is followed, the caustic soda being replaced by a solution of 26 lb. of carbonate of potash, or 2 gallons of caustic lye of 47° B. strength.

Similar means are adopted in the preparation of sulpholeates from olive oil, colza oil, or other seed oils. Oleine, too, may be sulphonated with at least 30 per cent. of 66° B. sulphuric acid, in order to obtain a stable soluble oil. These sulpholeates, however, being less stable than the sulphoricates, are frequently mixed with the latter when castor oil is dear.

These products are not met with in a concentrated state in commerce, but are sold in the condition of 40 to 50 per cent. oils. Their actual or commercial value depends on the strength; but it sometimes happens that the seller, who guarantees the buyer a 50 per cent. content, does not supply this, 50 per cent. of sulpholeate representing only about 40 per cent. of fatty acid. In fact, sulphonated and neutralised oil, even in the most highly concentrated form, only contains 80 per cent. of fatty substance. Care should, therefore, be taken to come to a proper understanding before placing an order for sulpholeates.

Soluble Oils for Machine Tools.—Engineering shops used to employ an aqueous solution of ordinary soap as a lubricant in drilling, milling, etc., or of oils for screw-cutting, etc. The soapy water oxidises the work, whilst the oils do not possess a sufficient cooling capacity to facilitate the operation of the tools; and, besides, pure oils are too expensive. These liquids have been readily and advantageously replaced by soluble oils. An oil of this kind, in order to satisfy the requirements of the engineer, should fulfil the following conditions:—

(1) It should be readily miscible with ordinary water, without separating out again during fairly long storage, and

without depositing a sediment in the storage receptacle. (2) The 1 : 10 aqueous solution should not readily decompose. (3) The liquid should not corrode the machine tools or the work; and, on the contrary, should protect them from rusting. (4) The oil should not have any unpleasant smell.

The neutral fats are insoluble in water, and will not mix with that liquid unless they are in the form of alkali salts. There is, therefore, no such thing as a soluble oil, properly speaking, but there are soluble soaps, or oils which are miscible with water by means of the soap they contain.

Two bodies which are not mutually soluble may become miscible on the addition of a third substance which is soluble in one or other of them, or when the mixture of the two ingredients is soluble in the third substance.

The oleate is more soluble than the stearate, and is more readily soluble in hydrocarbons when it contains an excess of olein, though the solution becomes cloudy when the excess is large.

A mixture composed of 1 part of oleic acid and 2 parts of mineral oil is cloudy or opalescent, but will clarify on the addition of 0.25 part of alcoholic alkali. If a larger proportion of alkali be added, the liquid becomes turbid at the plane of contact, but will clear up when the mixture is shaken, until 0.8 part of alcoholic liquid containing 8 per cent. of ammonia has been added. When this point has been reached the oil remains opalescent, even after prolonged shaking, the amount of alkali being excessive.

A mixture of equal parts of mineral oil, oleic acid, and the above alcoholic alkali gives a clear liquid which forms a stable, milky emulsion with 9 to 10 parts of water.

If 2 parts of liquid paraffin (*paraffinum liquidum*) be mixed with 1 part of oleic acid and 0.25 part of alcohol, a clear liquid is also obtained; but on the amount of alcohol being increased, the same turbidity occurs as when too much oleic acid or alcoholic alkali is used. The mixture turns cloudy first at the plane of contact with the alcohol, and then clears again on shaking; but when the proportion of alcohol reaches 0.8 per cent. an emulsion is formed.

The alcohol is the bond of union connecting the uncom-

bined oleic acid or its soap with the mineral oil. The alcohol, however, can be dispensed with when the soluble oil is a sulpholeate.

The quality of the resulting product is influenced by modifying the percentage proportions: a little more hydrocarbon, a little less oleic acid, an over-strong lye, too much or too little alcohol, and also by the presence of impurities in the raw materials. Any variation disturbs the equilibrium and produces a turbid oil, which gives a deposit, and will form a turbid emulsion with water.

The amount of soap required to emulsify the hydrocarbons with water varies according to their density and viscosity. The typical soluble oil is obtained in the laboratory by mixing vaseline oil (0.885) 60 parts, oleic acid 30, and alcoholic ammonia 15 parts. The density of this solution is 0.81, and it contains 9 per cent. of ammonia.

The light mineral oils and the rosin oils are more readily miscible with water than are the heavy petroleum oils; but the viscous oils have a greater power of covering the articles to which they are applied, and are better adapted for the preparation of soluble oils intended for use in screw-cutting and for other purposes where the lubricating action plays a principal part.

When the formula of the soluble oil has been ascertained in the laboratory from the tests made on the raw materials available, the work can be carried out with accuracy. In works practice the operator generally mixes the ingredients in accordance with a formula, which may be good, but which may become inaccurate when fresh batches of raw materials are used. In such cases the experience and the practised eye of the operator enable him to stop the admission of the lye or alcohol directly certain indications show that any further quantity would be harmful. For the beginner, however, it is preferable to determine beforehand the index of neutralisation of the mixture, since this enables the quantity of lye that may be added to be calculated.

Any excess of soda will make the oil cloudy and cause a separation of the resulting soap. The oleate formed in the unsaponifiable oil dissolves in the latter the more readily in

proportion as it contains oleic acid uncombined with soda; but this proportion of free fatty acid should be reduced to a minimum at the end of the operation, because the emulsifying capacity of the product increases with its soap content, the transparency and solubility of which should be obtained by the formation of fatty-acid salts in presence of an alcohol or of ricinic acid (which is at the same time a monobasic acid and a monatomic alcohol), rather than by a large excess of oleic acid.

The beginner can get his hand in by preparing a small quantity of soluble oil according to the two formulæ given below:—

1. American mineral oil (0·885) 56 parts, liquid saponification oleine (15") 28, ammonia (0·910) 5·5, denatured alcohol (90") 11 parts.

2. Russian mineral oil (0·900) 54 parts, filtered saponification oleine 26, caustic soda lye (40" B.) 10, denatured alcohol (90") 10 parts.

Method of Preparation. The mixed fatty substances are heated sufficiently and stirred in order to obtain a homogeneous, limpid mixture, which is then cooled down to 55° C. The alkali is introduced into the stirred mass in small quantities at a time, the liquid being allowed to clarify after each addition. This clarification will take progressively longer in proportion as the formation of soap in the oil proceeds, so that at length a stage is reached in which prolonged agitation is necessary to dissolve this soap, the excess of oleic acid, which at the start facilitated solution, being now almost completely neutralised by the alkali. At this point the further addition of alkali is suspended, and, after testing the emulsifying properties of the cloudy oil in a test tube, alcohol is added to the stirred mass by degrees until a test sample is found to be clear. The temperature of 50° C. should be maintained throughout the operation. The additions of alkali should be smaller in individual amount, and made at longer intervals, in proportion as the alkali used is more concentrated. Very strong alkali, however, produces granulation, in which case the lye should be diluted with a

little water, or preferably with a portion of the prescribed quantity of alcohol.

The following recipes, given in the final article of the series in the *Revue des Produits Chimiques*, from which these abstracts are taken, indicate the composition of commercial soluble oils. Some of them are miscible with pure water, others with slightly alkaline water; some will stand cold, and others separate out when kept in open receptacles. Some of the recipes will need to be modified to fit in with the materials available, and the objects desired; but the information already given will enable such modifications to be carried out after a few tentative experiments, the preparation of all the soluble oils being based on the principles already enunciated, it being always remembered that the preparation of a satisfactory product requires attention and some little practice.

Soluble oils sometimes decompose in store; two layers miscibles in water and granules are formed; the mass becomes gelatinous. This decomposition is the result of defective preparation, the evaporation of the alcohol or the volatile alkali, the ammoniacal soaps becoming dissociated at the ordinary temperature. A very low temperature also may lead to the separation of the components, but in such cases equilibrium is restored by warming. The formation of granules and gelatinous solidification may arise from an excess of alkali; and a sediment may be formed when the oil contains rosin that has been saponified by insufficiently strong alkali, or a rosin soap in which there is an excess of alkali.

Soluble Mineral Oils with an Olein Basis.—1. Mineral oil 63 parts, olein 21, caustic soda lye (35° B.) 7, alcohol (95°) 9 parts.

2. Mineral oil 55 parts, olein 30, ammonia (22°) 7, alcohol (95°) 8 parts.

3. Mineral oil 70 parts, olein 20, caustic soda (35° B.) 6, ammonia (22°) 2, alcohol (95°) 2 parts.

4. Mineral oil 70 parts, olein 10, refined rosin oil 10, caustic soda (35° B.) 4, alcohol (95°) 4 parts.

5. Mineral oil (0.905) 60 parts, olein 20, refined rosin oil 20, caustic soda (35° B.) 8, alcohol (95°) 1 part.

6. Mineral oil 60 parts, olein 25, strong rosin oil 5, ammonia (0.910) 8, alcohol (95°) 8 parts.

7. Mineral oil 65 parts, light rosin oil 9, strong rosin oil 4, olein 9, alcohol (95°) 8, caustic soda (35° B.) 5 parts.

8. Mineral oil 80 parts, olein 20, caustic soda (40° B.) 5, ammonia (0.910) 2, alcohol (95°) 1 part.

Soluble Oils with a Sulpholeate Basis. 1. Mineral oil (0.880 to 0.885) 60 parts, sulphoricinic acid 10, strong rosin oil 20, rosin 2, caustic soda (35° B.) 8 parts.

2. Sulphonated vegetable oil 14 parts, mineral oil (0.885) 45, strong rosin oil 18, olein 9, caustic potash (30° B.) 14 parts.

3. Sulphonated vegetable oil 74 parts, caustic soda (20° B.) 25, ammonia (22° B.) 0.6 part.

4. Sulphonated vegetable oil 84 parts, caustic soda (20° B.) 8, ammonia (22° B.) 2, rain water 6 parts.

5. Mineral oil 36 parts, sulphonated fatty acid 14, strong rosin oil 14, olein 20, refined rosin oil 10, ammonia (0.910) 6 parts.

6. Ammonium sulphoricinate 15 parts, rosin 5, rosin oil 15, olein 15, Russian mineral oil (0.905) 50, caustic soda (35° B.) 6 parts.

Soluble Rosin Oils. 1. Strong rosin oil 80 parts, alcohol (95°) 12, caustic soda (35° B.) 8 parts.

2. Refined rosin oil 70 parts, olein 16, alcohol (95°) , caustic soda (35° B.) 6 parts.

3. Strong red rosin oil 100 parts, carbonate of potash solution (40° B.) 10, ammonia (22°) 6 parts.

4. Refined rosin oil 40 parts, mineral oil 22, olein 20, ammonia (22°) 6, alcohol (95°) 12 parts.

5. Clear light rosin oil 42 parts, Russian mineral oil (0.905) 25, olein 20, ammonia (22°) 6, alcohol (95°) 7 parts.

6. Mineral oil 45 parts, refined rosin oil 13, sulphoricinic acid 13, olein 13, rosin 5, caustic soda (35° B.) 11 parts.

Soluble Oils Containing Rosin. 1. Mineral oil 80 parts, rosin 2, olein 18, caustic soda (35° B.) 5, ammonia (22°) 3, alcohol (95°) 1 part.

2. Rosin 30 parts, rosin oil 35, 10 per cent. solution of Solvay carbonate of soda 26, colza oil 8, ammonia (22°) 1 part.

To prepare the soluble oil of the last recipe the rosin is

melted by heat in the rosin oil until a clear liquid is obtained. This is saponified with the carbonate of soda solution added in small portions at a time, with stirring. The whole is boiled and stirred continuously to obtain a clear paste, free from water. The colza oil having been added, the mass is cooled before introducing the ammonia.

Certain low-priced soluble oils consist merely of a solution of resinate in mineral oil. They have the drawback of encrusting the pipes, and of depositing a pitchy crust on the work shaped by tools lubricated with resinate emulsions.

The following are the essential details of Boleg's Patent: To prepare pure neutral hydrocarbons such as mineral, rosin, and tar oils which shall be soluble in water and easily emulsifiable, the following process has been devised:—

The mineral oil to be prepared is put into a washing trough with a certain percentage of crude (but anhydrous) light-coloured rosin oil. The percentage may vary according to the specific weight of the mineral oil treated from about 15 to 25 per cent., and is there treated with direct steam at about five atmospheres pressure, which is distributed in equal finely divided portions throughout the oil. The mixture is boiled at not more than 100° to 105° C. at highest; then from 5 to 7 per cent. of caustic soda lye of 40° B \acute{e} . is added according to the specific gravity of the mineral oil, and the more or less admixture of rosin oil (say 5, 6, or up to 7 per cent.). The mixture is maintained for twenty to thirty minutes in a boiling state and treated until the oil is seen to clearly separate from the soap lye. After allowing the whole to stand from a half to three-quarters of an hour, the clear oil is drawn off, which takes with it 2½ to 3 per cent. of excess lye clearly saponified, over the underlying rosin oil soap solution to an oxidising apparatus, where the oil is treated with very finely divided compressed air for two hours at a temperature of 60° to 80° C. and afterwards for another hour at 80° to 110° C., for the purpose of supplying oxygen to the oil and causing its further saponification; the slowly evaporating water of the lye must be continuously added almost drop by drop during the course of the process. This oxidising process can also be attained by means of oxygen fluid

(ozone). Immediately after this oxidising process is finished, the oil is aspirated or blown directly into a pressure still and there treated with an addition of 3 per cent. alcohol (preferably methylated spirit), 2 to 3 per cent. strong ammonia solution, and preferably 1 per cent. of gelatine dissolved in water for half an hour to an hour under a pressure of 1 to $1\frac{1}{2}$ atmospheres at different temperatures until the originally turbid mass of oil and soap existing at the beginning of the process again becomes quite clear and easily soluble. The oil is now finished, but must only be drawn off after cooling in order to prevent the oils becoming turbid again.

It is to be noted that the addition of methylated spirit and ammonia, and also of the gelatine solution, is not absolutely necessary to this process, as it is in others, and is only recommended in particular cases so that the oils may dissolve rather more easily in the water and emulsify more easily and make the respective solutions permanent.

In the same way—that is, by using rosin oil (instead of fatty acid soaps)—tar oils soluble in water may also be manufactured.

In order to obtain these products with the required degree of permanency all the three processes must be carried out in their order, as if only one of them be employed the object desired is only partially attained. The soluble and emulsifiable oils and oil mixtures thus obtained can now be easily mixed with any quantity of water, and are specially applicable for the purposes mentioned below if further treated with 50 to 75 per cent. of distilled water (ordinary water can also be used) for a quarter to half an hour in the distilling or oxidation apparatus, when clear, in parts a trifle opalescent, but invariably permanent oil and water solutions of great value and universal applicability are obtained.

The mineral and rosin oils soluble in water or mixtures of the two kinds of oil may be employed with great advantage for the following purposes: (1) For lubricating, boring, cutting and polishing purposes. (2) For greasing wool before spinning. (3) For treating cloth in textile industries. (4) For colouring and glazing bricks and building stones. (5) For producing aromatic hydrocarbons soluble, in water

and the like, essential oils for disinfecting, soap manufacture, and perfumery purposes; as well as (6) for manufacturing soluble medicinal and pharmaceutical preparations of various kinds. The tar oils, soluble in water, are principally employed for disinfecting and preserving wood, and also for colouring and glazing bricks or tiles, and so forth.

The following physical and chemical points of interest are given in a memorandum on cutting lubricants and cooling liquids published by the Department of Scientific and Industrial Research:—

Cutting Oils.—The mineral oils, which are best suited to be used as cutting lubricants, either alone or mixed with animal or vegetable oil, are mineral oils, preferably of pale colour, of low viscosity, ranging from 100 to 200 seconds Redwood at 100° F. The lower viscosity oils may be used for high-speed conditions, and oils with higher viscosity may be used for slow-speed conditions. Of the animal oils used either alone or in admixture, tinged lard oil containing as much as 10 to 15 per cent. of free fatty acid is most frequently employed. Prime lard oil is almost free from acid; it is much more expensive than tinged lard oil, but is less inclined to gum under severe conditions (heavy cut and high speed). Lard oil congeals in cold weather, so that, where-ever possible, a mixture of lard oil and low cold test mineral oil is to be preferred on account of greater fluidity in the cold. Experience has proved that most cutting lubricants containing vegetable oils, particularly if they are heavily blown (*i.e.* thickened by oxidation), are liable to produce gummy deposits in circulation systems. These deposits interfere with the proper operation of the machine, and necessitate frequent cleaning of the machines, which not only increases the costs, but also decreases the output. Cotton-seed oil oxidises more readily than rape oil, and should not be used in the manufacture of cutting lubricants that are to be used in a circulation system. Animal oils are not so easily oxidised in a circulation system as are vegetable oils. Experience shows that lard oil only produces deposits in circulation systems under severe operative conditions, when the percentage of free fatty acid exceeds, say, 10 per cent.

When oils of low volatility are used a certain proportion of the oil is evaporated by the heat produced in the work; this is objectionable on account of the smoke and fumes created. Where cutting emulsions are used steam only is produced. Cutting oils are nearly always used "straight," i.e. without admixture of water. Certain cutting oils containing at least 5 per cent. of free fatty acid and preferably more than 20 per cent. of saponifiable oil (animal or vegetable oil) may either be used "straight" or in the form of cutting emulsions. They will emulsify with water to which the requisite amount of alkali (soda ash, borax, etc.) has been added.

Soluble Oils and Soluble Compounds. Soluble oils are prepared by dissolving a soap (usually less than 20 per cent.) in a mixture of mineral oil (usually less than 70 per cent.) and saponifiable oil (usually more than 15 per cent.). The saponifiable oils used in making the soap are either of animal or vegetable origin such as lard oil or other olein from animal fat, whale oil, wool grease, castor oil, sulphonated castor oil, rape oil, cottonseed oil, rosin, rosin oil, etc., and the oils are saponified by means of caustic soda or caustic potash. Some soluble oils or compounds contain a small percentage of alcohol or ammonia, which causes the emulsion to form more readily. When soluble oils containing ammonia are stored for several months in wooden barrels, the ammonia is sometimes absorbed by the barrel, and the oil is no longer completely soluble in water. With cutting emulsions made from soluble oils containing ammonia, the ammonia volatilises under severe conditions of service, and a scum is produced on the surface of the emulsion, which is objectionable, as it tends to clog the pipes in the circulation system, and by adhering to the swarf or chips causes considerable loss of oil. Soluble oils containing a large percentage of rosin or rosin oil have a tendency to cause gumming. Soluble compounds are made on similar lines to soluble oils except that they contain 10 to 50 per cent. of water and are in a semi-solid and semi-emulsified condition. They are not so easily mixed with water as are soluble oils, and for this reason the latter are usually preferred.

Analysis of Sulphonated Oils. The Oils Committee of the

British Section of the Society of Leather Trades' Chemists have issued their provisional Report in the *Journal of the Society*. In the first instance, work was done on the methods already proposed by the sister society in America, with the result that the following recommendations were made:—

Moisture.—A distillation method is recommended, using water-saturated xylol, or, as an alternative, a heavy mineral oil. The water distilled is collected in a Sutherland tube graduated to $\frac{1}{10}$ c.c.

Ash.—The total ash is determined by igniting 2·3 grams in a crucible.

Non-Saponifiables.—Ten grams of the sample is taken, and saponified by means of 2N. alcoholic KOH. This is preferred to the solution as recommended in the American method.

Total SO_3 .—The most satisfactory method is by alkaline fusion, splitting with hydrochloric acid not being favoured. (Dr. Turnbull and Prof. McCandlish pointed to the necessity of oxidising any sulphides formed during fusion by means of sodium peroxide or bromine water.) Further lines of investigation have been suggested.

Dr. Buncke, in the *American Leather Chemists' Journal*, has also contributed some interesting notes on the interpretation of analytical results in judging the practical value of sulphonated oils for leather purposes.

Analyses of two sulphonated oils are given, one of which stripped colours, while the other did not. In view of their completeness, the results are given in full:—

	A. Good Oil. Per Cent.	B. Bad Oil. Per Cent.
Water	25·13	29·45
The following figures calculated for dry oil:—		
Total fatty matter	93·680	92·570
" SO_3	3·157	3·919
" Na_2O	1·717	2·722
Ammonia	0·148	0·089
Glycerine, etc.	1·298	0·700
	<hr/> 100·000	<hr/> 100·000
SO_3 in salts	0·557	1·206
Comb. SO_3	2·599	2·712
Sulpho. fatty acid	12·340	12·880
Neutral oil	31·990	39·730
Ash	4·070	6·320
Fatty acid in soap	5·26	8·70
Free fatty acids	56·43	44·14

The remarks upon the above analyses made by Dr. Buncke are: There is a difference in their behaviour in water; (A) dissolves easily, while (B) dissolves but slowly. This is because the latter contains more Na_2O , and consequently more soap than (A). There is not much difference as regards degree of sulphonation, but, if anything, (A) is the better in this respect. This is indicated in the original analysis, *i.e.* including moisture. The reason for stripping of colours appears to be the greater amount of soap in (B). Other examples are given in this paper, to which the reader is referred for fuller details. (*Jour. Amer. Leather Chem. Assoc.*, 1919, No. 9.)

Mineral oil emulsions are also formed according to the patent of E. Korndorfer, Bohemia (Eng. Pat. 14,294, 1905), by mixing together 10 to 30 parts of an alkaline-earth sulphoricinoleate (prepared by acting on an alkaline compound of a sulphonated oil with a metallic oxide which forms a soluble compound), 10 to 30 parts of olein, oleic acid or stearin, 30 to 70 parts of a mineral oil, spindle oil, or vaseline oil and $2\frac{1}{2}$ to 10 parts of ammonia (specific gravity about 0.910).

E. Junginger (Fr. Pat. 366,293, Mar. 29, 1906) also forms a soluble mineral oil by adding to a magnesium compound of a sulphonated oil an equal weight of oleic acid, with sufficient ammonia to neutralise the latter and render the liquid clear and incorporating this with a mineral oil.

CHAPTER XIX.

SUBSTITUTES FOR LUBRICATING OILS.

VIEWING to the shortage of lubricating oils during the last few years many attempts have been made to replace them with other liquid products.

In the patent of E. A. Emery (Eng. Pat. 14,263, June 21, 1906) claim is made for a hygroscopic solid lubricant for pneumatic machinery, the ingredients of such material being soap or a saponaceous substance, plumbago, and a liquid extract of slippery elm bark, to which is added a salt to serve as a non-refrigerant and water to render it sufficiently plastic.

The Chem. Fabr. von Heyden, A.G. (Ger. Pat. 288,448, Mar. 18, 1915), state that the phosphoric esters of phenols may be used in place of lubricating oils. In the case of solid esters their melting points may be lowered by the addition of other substances, such as cresyl phosphates. In another patent (Ger. Pat. 302,361, Feb. 27, 1917) they also claim the use of tricresyl phosphate as a substitute for lubricating oils.

According to the patent of the Ges. m. b. H., Berlin (Ger. Pat. 306,836, Mar. 7, 1916), hydrogenated products of naphthalene, *e.g.* tetrahydronaphthalene and decahydronaphthalene, can be used in place of lubricating oils either alone or in admixture with fats or mineral oils.

Chlorinated products of naphthalene have also been recommended for the same purpose. These are formed by the action of chlorine upon naphthalene with the aid of a catalyst such as aluminium chloride, with or without pressure. The products are neutral and inert, and are practically unflammable (E. Stern, Ger. Pat. 302,986, Mar. 31, 1916).

Another lubricant claimed by C. F. Astell (Assignor to J. P. Amend, U.S. Pat. 1,226,165, May 15, 1917) consists of a 30 per cent. solution of calcium chloride with the addition of graphite and alcohol.

CHAPTER XX.

THE APPLICATION OF LUBRICANTS TO MACHINERY.

IN practice, it is not sufficient merely to employ the best lubricants, but it is requisite also to use them in the most economical manner. The consumption of a small percentage more of the oil than is necessary is by no means a matter of indifference to a manufacturer with a large number of machines in constant work, since the increased amount considered due to defective application amounts to a considerable extra outlay per annum in a large establishment.

To obviate this, the first point is to select the most suitable lubricant for the machinery in question, and then apply it by the aid of appropriate lubricators.

These appliances are now made in various types, according to the kind of lubricant used and the construction of the machinery. Thus, for instance, no special appliance is needed for ordinary carts, the wheels being merely taken off and replaced after the grease has been smeared on the axles; whereas vehicles of superior type, such as carriages, are fitted with oil containers, which being kept filled lubricate the axles continuously. This continuity of lubrication is indispensable in the case of axles running at high speed, such as those of railway waggons and locomotives; for axles of this type special grease boxes are fitted, which being filled with grease, deliver it uninterruptedly to the axles through small orifices provided for the purpose. The construction of these grease boxes varies according to the class of solid or liquid lubricant used, and all more or less fulfil their purpose of supplying the axles with just sufficient lubricant without allowing any to run to waste.

The large number of different types of grease boxes designed and used affords sufficient proof of the considerable

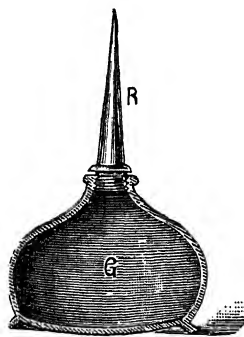
difficulties attending their construction. On this point the interested reader is referred for detailed information to the technical literature on the subject, the construction of these appliances falling within the domain of mechanical, rather than chemical, technology.

A brief description of the principal lubricators designed for use on different classes of machinery may not, however, be out of place.

The Flexible Oil Can.—This small vessel, which does excellent service for small machinery, is illustrated by Fig. 14, and consists of a metal case G, with a fine tapering nozzle R, terminating in a small orifice screwed into the case G. The bottom B of the can is convex, and being made of flexible sheet metal.

When this can is filled about two-thirds with oil and is inverted, the application of pressure to the bottom B with the thumb, compresses the air within causing it to press on the oil, which now occupies the tube R, thus forcing a drop out of the nozzle. The number of drops expelled in this way depends on the amount of pressure exerted on the bottom of the can.

On reversing the can again, more air enters through the nozzle, so that each time the bottom is pressed, any convenient number of drops of oil can be forced out.



B
FIG. 14.

This class of can is very largely used for oiling sewing machines, embroidering machines, small planing and drilling machines, turret clocks, and in fact for all kinds of small delicate machinery not run at such high speed as to require the use of continuous lubricators.

Although the practice would increase the cost of these cans, it is recommended that they should be lightly plated with silver on the inside, instead of being simply of ordinary sheet brass or zinc. This slight addition to the cost would be more than repaid by the certainty that good lubricating oils, such as bone oil, would keep perfectly colourless and

fluid for many months (as the author has proved by his own experience), whereas in brass cans, they soon acquire a greenish tinge and become more or less thickened. This is due to the metal being corroded in presence of air, the copper combining with the fatty acids of the oil furnishing a compound which renders the latter green and thick.

The Aerostatic Oil Can.—For large machinery, such as vertical and marine engines, boring machines, spinning and weaving machinery, etc., the author's experience goes to show that there is no better lubricator than the aerostatic oiler, which unites in itself a number of excellent qualities. Like the flexible can, this oiler is only suitable for fluid lubricants.

As shown in Fig. 15, this can consists of an elongated body G, on which are soldered a long bent spout R, tapering to a fine nozzle, and a handle H. The form and length of the spout vary according to requirements, but in all cases it must

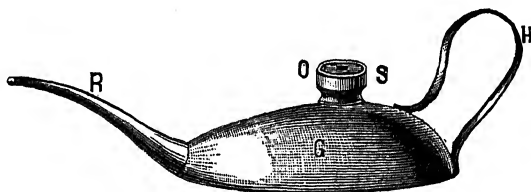


FIG. 15.

be long enough to enable the attendant to put the can into position for oiling without danger to the hand from the running machinery.

At the highest part of the dome on the can body G is an orifice closed by a metal screw cap, which is dished at the top and is perforated by a fine bore.

The can is filled through O, after the screw cap has been removed, the latter being then screwed on again. In use, the can is held by the handle, the thumb being applied to the small opening in the screw cap, in which case only one or two drops of oil is discharged when the can is tilted, the backward pressure of the external air on the liquid preventing it from running out more freely.

On removing the thumb from the cap, air enters the can through the bore, and the pressure being equalised a stream of oil flows from the nozzle of the can. In this

way the outflow can be regulated from a single drop to a continuous stream, or stopped altogether. The manipulation of this can is learned in a moment, so to speak, as soon as it is taken in the hand; and if the user employs sufficient care, not a single drop of oil need be wasted.

The Oil Cup.—For large shafts or axles the oil cup (Fig. 16) is used. In its simplest form this cup consists of a small vessel G, which is mounted on the bearing of the shaft A, and is closed by a tight-fitting hinged cover, to keep out dust. A small conical tube R in the bottom of the cup allows the oil to flow down to the shaft, through the bearing.

The oiler fills the cup full of oil (preferably from an aerostatic can), and knows from experience how long this quantity will last. It is important to make the cup G rather shallow, and the tube R very fine otherwise the column of oil being too high would exert an excessive pressure, thus causing a larger flow of oil from the cup than is necessary for lubrication.

Some machine parts being constantly in motion need continuous lubrication, whilst their inaccessibility precludes oiling by hand without stopping the machine. Devices are, however, provided for enabling this operation to be performed in a continuous manner while the machine is running. One of these is shown in Fig. 17, and is particularly recommended on account of its simple construction and high efficiency.

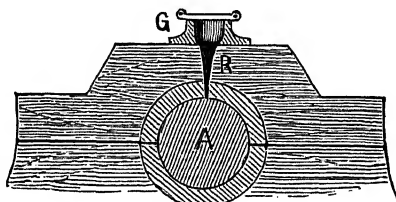


FIG. 16.

The drawing represents a ring R, running on a disc mounted on the shaft A and in contact with the ring at all points of the circumference. Hence the surfaces in contact between the parts R and S must be lubricated. Now, an ordinary oiling cup would throw the oil about, owing to the continuous movement of R: therefore to prevent this, a moveable oiler is employed. This consists of a glass bulb G, which is screwed on to the ring R by means of a metallic mount. The mount carries an upwardly evased cone valve V,

fitted with the stem S, whilst a narrow bore B leads to the contact surface between the ring and the disc.

To fill the oil bulb G it is unscrewed and inverted. The valve V is then closed by pulling at the stem S, the bulb is turned the right way up (no oil escaping), and is then screwed back on to the ring. The stem S is made long enough to raise the valve a little when the bulb is screwed home. The oil flows through the small orifice thus provided, and keeps the ring R supplied with oil until the contents of the bulb are exhausted. From time to time a bubble of air forces its way into the bulb, to replace the removed oil.

There are also a number of appropriately constructed

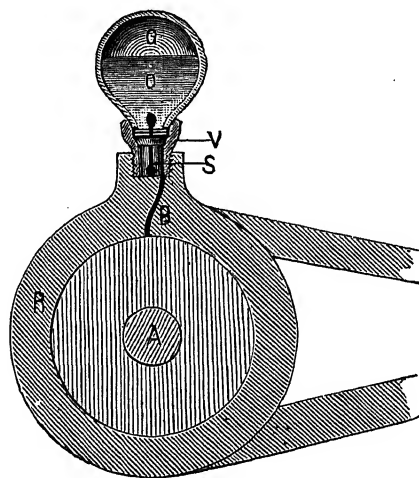


FIG. 17.

lubricating appliances, working automatically, for oiling moving parts of machinery. It being highly desirable to determine what quantity of oil is consumed under different circumstances, we will now describe an apparatus well adapted for this purpose (Fig. 18). From its mode of action it may be styled a drop-cup oiler. The vessel for holding the oil is made of glass, and the oil outlet at the bottom is enclosed between two panes of glass, so that the dropping of the oil can be observed. The delivery orifice may be controlled by a cone valve, which is attached to and turned along with a filling cup. The periphery of the metal mount surrounding the glass cylinder is graduated into, say, ten parts of equal

size; and a pointer attached to the regulating cone moves over this scale. When the pointer is opposite the zero mark, the oil outlet is closed; when it is opposite 9 on the scale, the maximum amount of oil is being delivered per unit time. The quantity of oil needed to fill the oiler being accurately known, once for all, the consumption of oil under certain given conditions can be easily calculated from the time required to empty the cylinder of oil when the pointer is opposite different divisions on the scale.

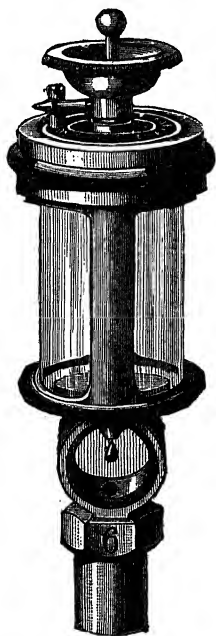


FIG. 18.

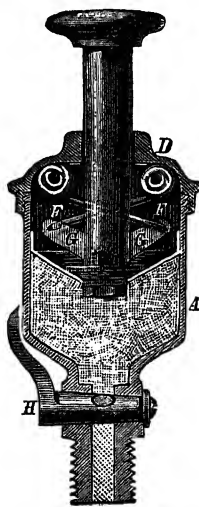


FIG. 19.

A great improvement on the ordinary sight feed lubricator is the "Kirkham" Patent Snap Drop Oiler (Fig. 20). This is screwed directly into the bearing and instead of having an opening below through which dust could penetrate, the flow of oil is observed through the glass vessel by the speed of the air bubbles which rise in the container as the oil flows out. The flow of oil can be very accurately regulated by turning the screw at the top of the oil container.

Fig. 21 shows the "Kirkham" patent lubricator, made by the Valvoline Oil Co. for the lubrication of engine

cylinders. The form illustrated is of 1 gallon capacity with four independent pumps and feeds, one of which is shown. A reciprocating motion derived from any suitable moving part of the engine is conveyed through the rocking rod H, oscillating shaft and pendulum direct to the rams. On the suction stroke the rams draw the oil from the container

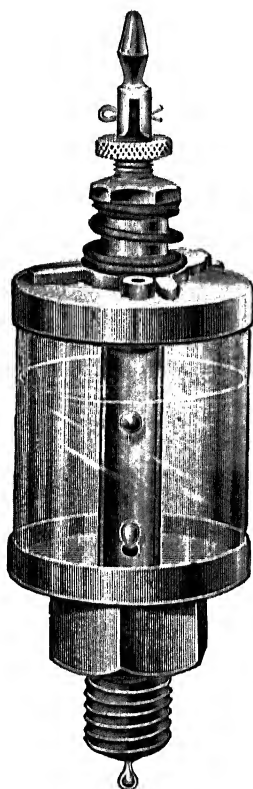


FIG. 20. The "Kirkham" patent snap drop oiler—with air globule sight feed, for lubricating bearings.

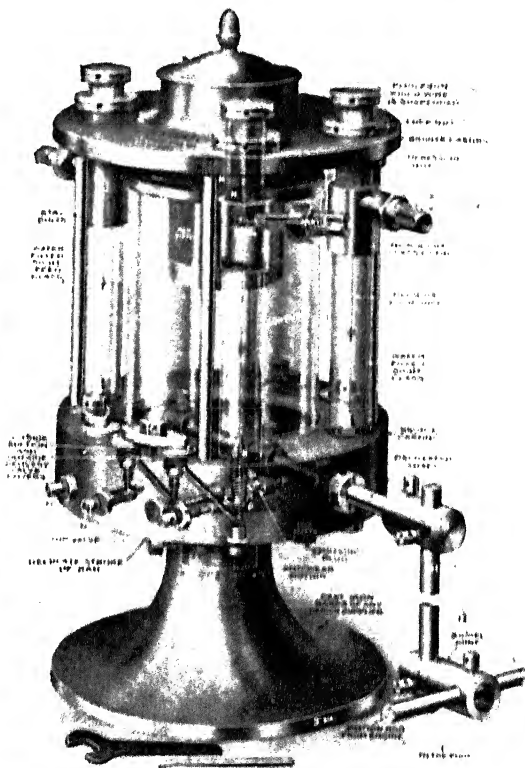


FIG. 21. The "Kirkham" patent (engine cylinder) lubricator.

through port Q and suction valve R, following the course shown by the white dotted line to the rams. On the delivery stroke of the ram the oil is forced through delivery valve P, along the passage to valve P, on to nozzle B, making a portion only of a full globule, which, after a number of deliveries,

forms a complete globule on the sight glass guide wire; then floating up it, through the water, it unites with the oil above the water.

The parts from nozzle B to the end of the oil pipe, which projects into the steam chest, are always full of liquid, water in the sight feed and oil in the pipes to the engine, as a consequence, with each delivery of oil on to the nozzle B, there is a simultaneous ejection of oil into the steam. Each of

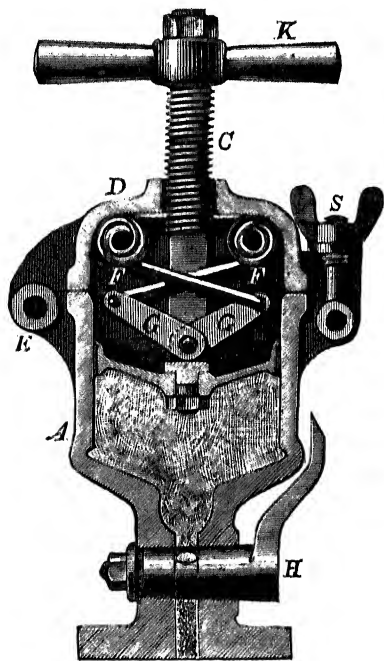


FIG. 22.

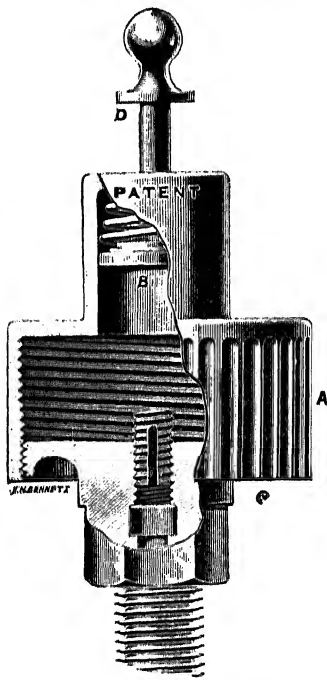


FIG. 23.—Patent automatic lubricator. Trier Bros., Ltd.

these ejections enters into and synchronises with the intermittent rushes of the steam which ensures the thorough diffusion of the oil. Each feed is separately regulated by an external adjuster (marked "Regulator") by which the stroke of each individual ram can be separately adjusted to the feed desired from each.

The working of this lubricator is automatic and exceedingly regular, and it requires practically no attention except that of filling the reservoir with oil,

For thick or buttery lubricants, greasers are used in which the lubricant is kept pressed against the part to be lubricated. In the Reisert spring greaser (Fig. 22) this pressure is exerted by spiral springs *P*, which press on the elbow piece *G*, and through this on the piston in position over the grease in the cup *A*. To maintain the piston in its highest position when the cup is quite full, there is a small peg on the piston rod which holds the piston in place when turned round. To

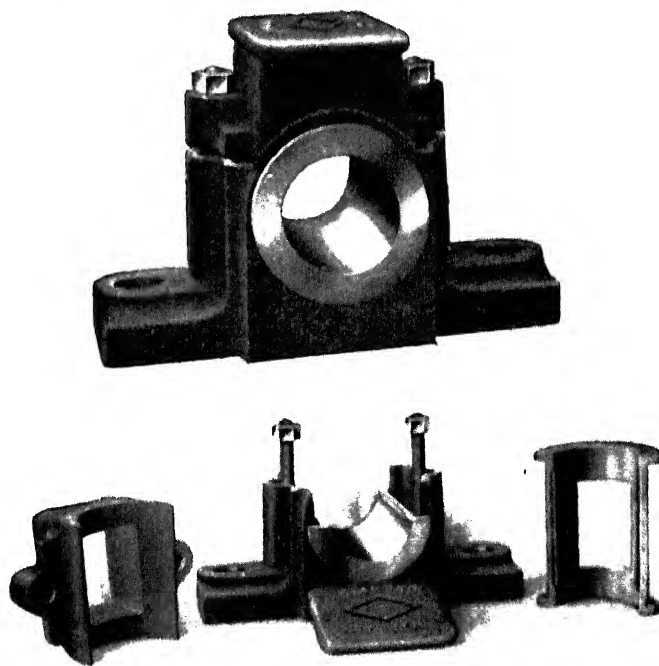


FIG. 24. Diamond Grease Lubricator. Diamond Lubricating Co., Ltd.

fill the cup, the cap is unscrewed, and the piston and its fittings removed. When the machinery stops running, the further outflow of grease is prevented by turning the tap *H* below. The cup is refilled by loosening the screw *S*, and tilting the upper part of the greaser back, on the hinge *K*.

The Automatic Combination "Tell-Tale" Lubricators, Fig. 23, made by Trier Bros., Ltd., Westminster, London, are excellent for applying the solid Stauffer's lubricant, these are

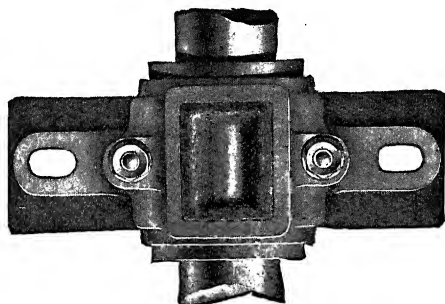


FIG. 25.

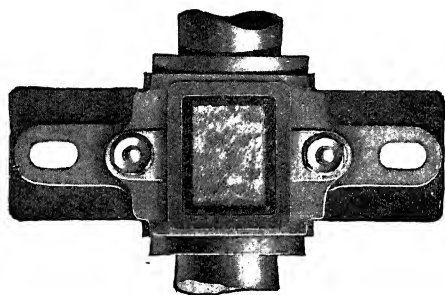


FIG. 26.

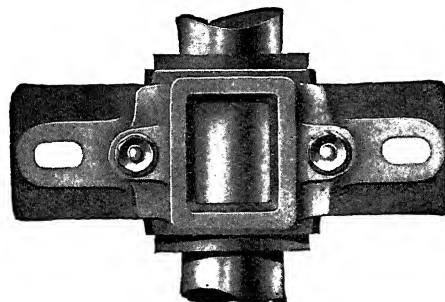


FIG. 27.

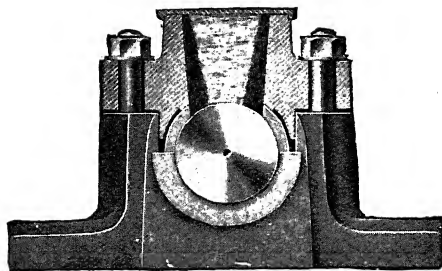


FIG. 28.

of many different forms and can be fitted to any part of a machine. The piston rod is threaded and traverses a nut in the cap, so that it can be screwed up or down. They act by screwing down the nob D, which puts the material under the constant pressure of the spring B.

Figs. 24 to 28 show a form of lubricator made by The Diamond Lubricating Co., Ltd., Wexley, Manchester, for the application of their special Diamond Grease to bearings. Fig. 25 shows the holder from above; Fig. 26, Diamond Yarn in position; Fig. 27, Diamond Grease and Yarn in position; and Fig. 28, a section of the bearing and grease box.

CHAPTER XXI.

TESTING LUBRICATING OILS.

IN the testing of lubricating oils various physical and chemical data are determined, such as specific gravity, flash point, viscosity, iodine value, acidity, etc., but these belong to the province of analytical chemistry and will be found fully described in works on oil analysis, such as Lewkowitsch's *Analysis of Oils, Fats and Waxes*, Allen's *Organic Analysis*, and others, but however useful such tests may be it is sometimes desired to know how a lubricating oil will behave when submitted to the conditions actually existing during use.

For this purpose the Thurston Patent Oil Tester, Fig. 29, made by W. H. Bailey & Co., Ltd., Salford, may be employed.

Fig. 29 is a sectional illustration of the testing machine showing its construction. In carrying out a test the pendulum H, H is removed from the testing journal G, G, the machine is adjusted to run at the desired pressure by turning the screw head K projecting from the lower end of the pendulum until the index M in front of the pendulum shows the proper pressure, the machine is then adjusted to run at the right speed, which is usually 2250 revolutions per minute, equal to a speed of rubbing surface of 736 feet per minute. The bearings are then thrown out by means of the two thumb screws on the head of the pendulum, and the pendulum is carefully removed from the testing journal G, G, taking care that no scratching of journal or brasses occurs.

A few drops of the lubricant are placed on the journal, the pendulum replaced and also the portion H, H and the machine is then run for a few moments to ensure that the oil is well distributed over the journal. The machine is

then stopped, and the nut or cams which confine the spring are loosened, and when it is in contact and bearing on the lower brass with full pressure the nut or cams are turned out of contact so that the springs may not be jammed by their shaking back while working. The machine is again started and run until the test is completed. At regular intervals of say one minute or more an observation of the thermometer Q is made and the temperature recorded, the position of the pointer O on the arc P is also noted and when

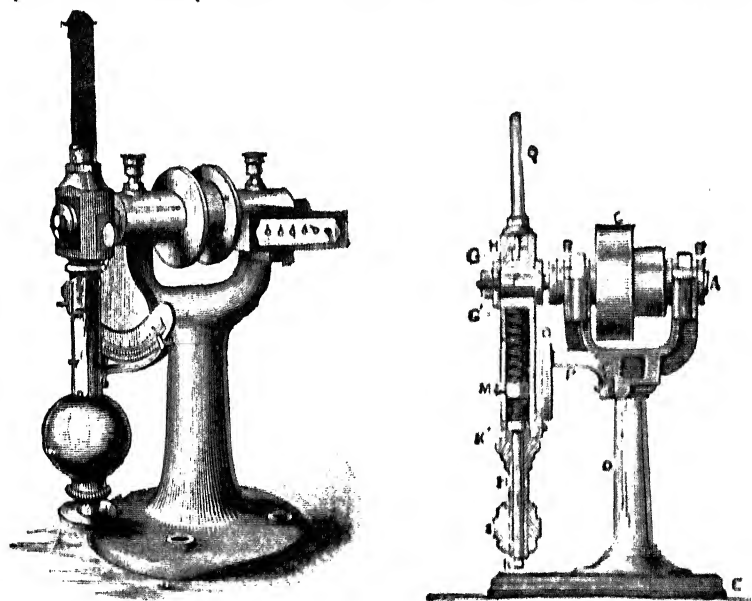


FIG. 29. — Bailey's Thurston's patent oil tester.

these two factors become constant the experiment is completed.

Immediately the test is finished the pressure on the spring is relieved, the pendulum removed and the journal and brasses are cleaned with extreme care, so that no scratch or injury occurs to them or particle of lint is left behind.

Taking the pressure on the journal and the reading on the arc the coefficient of friction is obtained by reference to a table which the makers have prepared.

The tendency of an oil to gum may also be determined on this machine by allowing the oil to remain on the journal

twelve or twenty-four hours and then run for a few moments, when the reading on the arc P has fallen to a minimum and begins to rise again the machine is at once stopped. The minimum coefficient compared with that of other oils will show the comparative liability to gum, the oil giving the lowest figure being the least likely to gum in the period of time covered by the test. The durability of an oil is also determined by a definite number of drops of oil flowing on the journal and running the machine until the friction shown on the arc is double the minimum or until a definite rise of temperature, say 212° F., is noted. A number of tests are made and the average time taken. Then either the time required, the number of revolutions, or the distance rubbed over the bearing required to raise the coefficient of friction or the temperature to the extent mentioned may be taken as a measure of the durability of the oil.

With lubricating oils, which under working conditions are subjected to high temperatures, the conditions of testing have to be modified, and for testing such oils Boulton's Patent "Cylinder Lubricant" Tester has been devised and is made by the same firm.

In this form, Fig. 30, A is the thermometer, graduated in degrees Fahrenheit and in corresponding steam pressures, B, B are set screws used for compressing the spring E, D, D is an expanding friction journal, E the spiral spring expanding on D, to produce friction, and F the burner for applying heat. In commencing a test the set-screws B, B are tightened in order to depress the spring E and the friction surfaces can then be examined to see that they are perfectly clean, the cylindrical bath is then lifted away and a measured quantity of oil is poured on and the cylinder bath replaced in position. The set-screws B, B are slackened to allow the spring to exert its full pressure and the Bunsen burner is then lighted. As soon as the thermometer indicates the temperature at which the test is to be made, the machine is run until a 50 per cent. rise of friction occurs in excess of that indicated by the dynamometer pointer at the commencement of the experiment. The time is then a measure of the lubricating value of the oil at the particular temperature to which it is sub-

jected, and naturally the shorter this time is the poorer will be the oil. It is not necessary to confine the tests to a 50 per cent. rise, in some cases a 100 per cent. rise may be preferable, but it is not advisable to exceed this since injury to

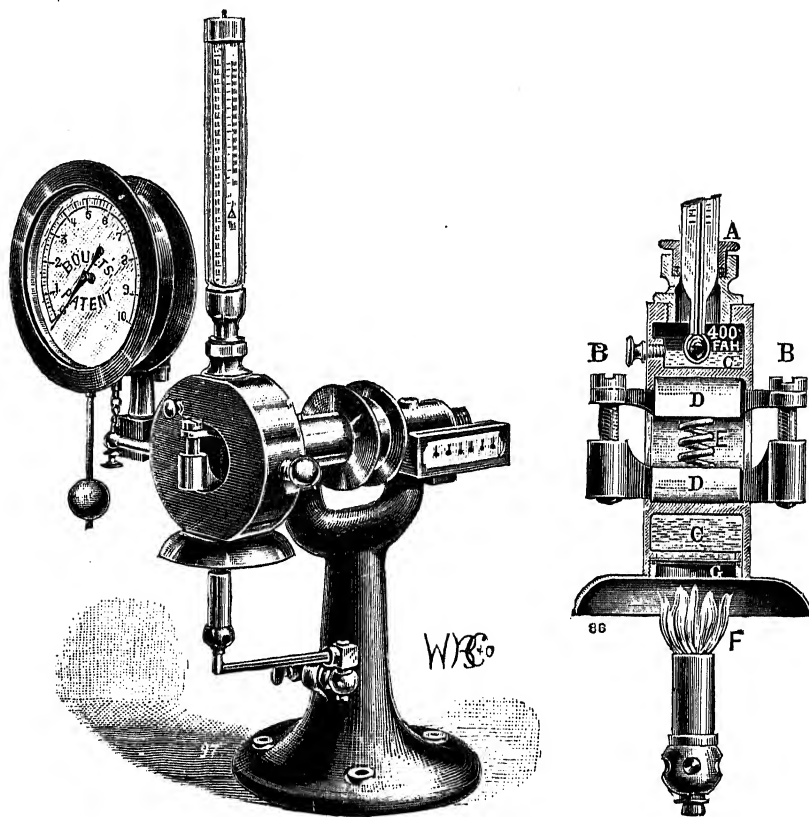


FIG. 30.—Bailey's Boulton's patent "cylinder-lubricant" tester.

the machine might otherwise occur. The machine is usually run at a speed of 500 or 600 revolutions per minute, but for quick-speed engine oil 1000 revolutions could be employed. The speed must, of course, be constant throughout the duration of the test.

CHAPTER XXII.

REMOVING THICKENED GREASE AND OIL.

Those who have the control of machinery are aware that a machine that has been out of use for some time cannot be started again until it has received a thorough cleaning. This is especially the case with regard to the lubricated parts, since the old grease or oil not only dries to a tough thick mass, but mixes with dust gathered from the air, and forms such a thick, hard crust, that in many cases it can only be scraped off with great difficulty.

To clean a machine that has got into this condition, it must first of all be taken to pieces, as far as possible, and the various parts dealt with separately. In carrying out this work, the kind of oil used must be borne in mind: whether solid or liquid fat, soapy or mineral oil lubricant.

If this information is not available, the nature of the old lubricant must be determined by an experiment. If a fatty lubricant has been used, it may be removed by treatment with caustic soda; the same also yields to soapy lubricants. Mineral oils, however, cannot be entirely removed by this treatment, but require a longer or shorter soaking in petroleum before they can be loosened. Machine parts that are covered with old fatty or soapy lubricants must be scrubbed with caustic soda lye until quite clean; after which they must be repeatedly washed with water, in order to remove the last traces of alkali, or they will soon rust. Finally, they should be rubbed dry with a soft cloth and smeared with petroleum jelly, being then stored in a place out of contact with dust, until the machine is put together again.

Metal parts covered with thickened grease that is soluble in petroleum are placed in a vessel of sufficient size, and petroleum is poured over them. After a time the lubricant

will be either dissolved or so far loosened that it can be removed without difficulty. They may be left until the adhering petroleum has evaporated, and are then ready for immediate use.

Both mineral oil and fatty lubricants can be removed much more quickly by the aid of benzol, and hence this solvent is particularly recommended for cleaning fine and delicate machine parts. Thus an old watch that has lain unused for a long time, so that the lubricating oil has become perfectly thick, can be cleaned ready for immediate use, by soaking it in benzol for a few days and then leaving it to dry in the air for a time. Sewing machines are best cleaned with petroleum or benzol. This operation is preferably performed in daylight, since both petroleum and benzol give off vapours which form an inflammable mixture with air, and one that may explode with violence if ignited by a flame.

CHAPTER XXIII.

CLEANING OIL RAGS AND COTTON WASTE.

IN establishments where a large quantity of machinery has to be oiled and cleaned, it is quite a profitable undertaking to recover the oil, etc., absorbed by the cleaning rags and cotton waste, and bring these materials into condition for use again.

The best method of accomplishing this is based on the circumstance that all the bodies used as lubricants are soluble in petroleum ether (light petroleum spirit) or benzol, both of which are obtainable at low prices. The lubricants are dissolved in one of these solvents, and recovered by expelling the latter by evaporation, the solvents being also recovered for use again.

For this purpose the greasy rags and waste are packed pretty closely in an iron drum, fitted with a draw-off tap at the bottom and a tight-fitting cover. Before fastening down the lid, a sufficient quantity of one of the above solvents is poured into the drum to cover the rags after the latter have taken up as much as they can absorb. The lid is then fastened down and the drum left for twelve hours, at the end of which time water is poured into a tube, about 6 feet long, projecting from the lid of the drum, and the draw-off tap at the bottom is opened. The dissolved lubricant runs out, being displaced by the water, more of which is added until clear water begins to flow from the bottom tap, showing that the oil and solvent are all out.

The dissolved lubricant is next transferred to a still, which is placed in a water bath, the latter being then heated to boiling point. The solvent, boiling at a lower temperature, is completely evaporated, and can be recovered by means of

a condenser, leaving the recovered lubricant in a fluid condition in the still.

It has been recommended by some that the greasy rags should be treated with solvent in a closed metal vessel, then quickly pressed, and the solution distilled. Experience shows, however, that even when the rags are pressed as quickly as possible, a good deal of the solvent is lost by evaporation, so that the recovery of the lubricant does not pay.

Rags soaked with fatty lubricants may also be cleaned by saponification. For this purpose they are placed in a pan, mixed with weak soda lye, and then boiled, one or two specimens being taken out from time to time to see whether all the fat is saponified. When this stage is reached all the rags are taken out, and the boiling is continued until a finished soap, of low quality, is obtained.

Cleaning rags or waste impregnated with mineral oils or paraffin grease cannot be cleaned with caustic soda, but must be treated with one or other of the above solvents.

Storing Greasy Rags or Cotton Waste. A word of caution should be given on the subject of storing greasy cleaning rags or cotton waste. It has often been observed that rags soaked with fatty lubricants are liable to become heated when kept in heaps, the temperature rising to such an extent that they take fire and may cause immense damage.

The only explanation of this phenomenon is that the fat is exposed upon such a large surface to the air that it readily oxidises, the heat thus liberated being sufficient to induce ignition. Consequently, strict orders should be given that all oily rags and cotton waste are to be put into special iron drums, with tight-fitting covers. In this way the risk of fire is reduced to a minimum; should heating occur, this can only take place to a limited extent and would not in any case reach ignition temperature.

Purifying Waste Lubricants. In many machine parts requiring copious lubrication, a considerable amount of oil runs away and is caught in collecting vessels placed beneath. This waste oil is generally contaminated with dust and very small particles of metal, which can be removed by filtration through two or three layers of thick blotting paper, the re-

covered oil being then suitable for use again. Where small quantities are to be dealt with, the filtering apparatus need only be very simple; but for larger amounts, specially constructed appliances are necessary, especially in the case of viscous lubricants.

Of this type the apparatus of Heitmann & Co. (Fig. 31) is a good example. It consists of a cylinder divided into two compartments, A and C. The lower compartment A is charged with the oil to be filtered, and is fitted with a heating

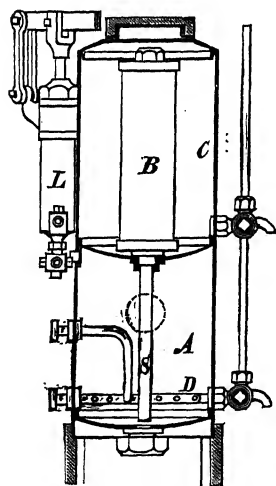
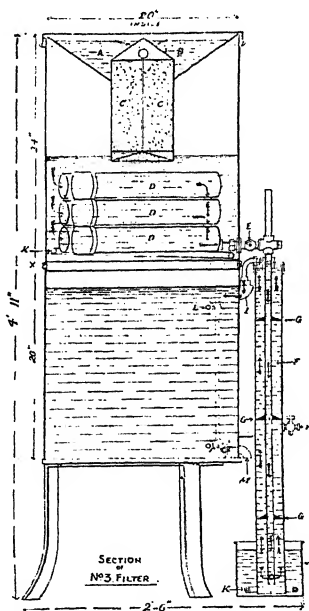


FIG. 31.

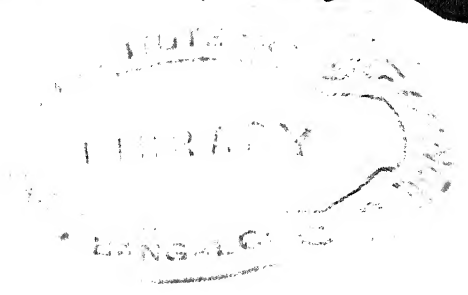
FIG. 32.—Turner's patent oil filter
(Valvoline Oil Co.).

coil to increase the fluidity of the oil; whilst C contains the filter B, which is connected with A by the pipe S.

The oil in A is caused to flow through the pipe S, either by introducing steam into A or by exhausting the air from C; and in this manner the oil is filtered into C.

A very efficient filter and purifier for treating dirty oil is the *Turner Patent Oil Filter* made by the Valvoline Oil Co., and shown in Fig. 32. This consists of a cylindrical chamber divided into two compartments and surmounted by the tray

A, into which the dirty oil is poured ; this is kept filled so that it covers the perforated cap B, through which it passes to the cylinder C. In A the heavier part of the dirt settles out and this, being removed from time to time, saves the clogging up of the filters. The oil passes through the cylinder C and the cylinders D, D, which are packed with a special kind of waste, and then through F to the bottom of the water column F ; in F it rises through the water being broken up into small drops by the perforated zinc cones G ; from the top of F it passes through I into the lower part of the cylinder or filtered oil container. N is a cock for drawing off water and dirt, H is a cock for drawing off excess of water, and L is a glass gauge for showing the height of the filtered oil.



CHAPTER XXIV.

THE USE OF LUBRICANTS.

DIFFERENT purposes entail the use of different lubricants. True, one often hears of so-called "universal" lubricants, which, however, never succeed in doing all that is claimed for them; and indeed the title at once implies that their makers are ignorant of the nature of lubricants, for there is no such thing possible as a universal lubricant.

It can be readily understood that the shaft of a flywheel weighing perhaps several tons, and running at a comparatively low speed, will require an altogether different kind of lubricant from the axles of an express train.

Machines running under a light load will require still another kind of lubricant, the chief point being to employ one that will reduce friction to a minimum and consequently diminish the wear and tear, whilst ensuring easy running of the parts.

Very fine and small machinery, such as that of clocks and scientific instruments, require lubricants that, in addition to minimising friction, will remain unaltered, or nearly so, during a long period of time, neither thickening, "gumming," nor corroding the metal, even in the course of years.

In works' machinery, vertical and marine engines, one lubricant will suffice, as a rule, for all seasons of the year, the machines being placed indoors and exposed to a fairly uniform temperature. The conditions are different with locomotive machinery, *e.g.* railway axles, which are exposed to the greatest summer heat and winter cold. In climates where there is a wide difference between these extremes, a single lubricant will not suffice for this class of machinery, but the composition must be modified according to the period of the year.

In the case of a lubricant, otherwise suitable, the degree of fluidity must be taken into consideration; the thinner it is the higher the rate of consumption as a rule. This is a factor deserving notice, especially in lubricants for the axles of vehicles.

For railway companies, the consumption of a minute quantity, more or less, of grease per axle monthly is by no means an unimportant matter, the difference amounting to a considerable item of expenditure in view of the very large number of axles to be greased.

We have not yet arrived at the stage of being able to assert with perfect confidence that such or such a lubricant is the best, most efficient, and most economical for a given purpose, some experts praising lubricants that are decried by others. The sole way to form a reliable judgment of the suitability and good and bad properties of lubricants, is by making prolonged and exhaustive tests with a number of these articles on a large scale.

With lubricants that are used only in small quantity for fine machinery, price is a secondary consideration, the chief point being to obtain preparations that satisfactorily fulfil the purposes of lubrication: diminution of friction, conjoined with perfect preservation of the machine parts.

PART II.

SHOE POLISHES AND LEATHER SOFTENING PREPARATIONS.

CHAPTER XXV.

THE MANUFACTURE OF SHOE POLISHES AND PREPARATIONS FOR VARNISHING AND SOFTENING LEATHER.

THE preparation of these articles is a branch of chemical industry which is highly profitable, but is carried on in such a manner, in many instances, that the products, although of a fine deep black colour and giving a beautiful polish, affect the leather in a highly undesirable manner, rendering it brittle and liable to crack.

Most of the preparations used as shoe polishes consist of syrup, sulphuric acid, and bone black or lamp black, incorporated with a suitable proportion of low class fat, such as fish blubber, rancid lard, etc.

When bone black, *i.e.* powdered carbonised bones, is mixed with sulphuric acid, the calcium phosphate in the black reacts with the acid to form calcium acid phosphate and calcium sulphate, the finely divided carbon in the black being set free and imparting to the polish its deep black colour.

The syrup also undergoes a change when brought into contact with the acid, carbon being liberated. The addition of fat facilitates the application of the polish to the leather, and helps to obtain the polish when brushed for a short time.

Bone black may also be replaced by lamp black or vine black: this modification being attended with certain advantages over recipes containing sulphuric acid. When this acid is used it is necessary to employ only just so much as

will be fully neutralised by combination with the calcium phosphate of the bone black, since any excess of free acid will gradually destroy the leather to which the polish is applied. The leather will become covered with fine cracks, and will finally break in a number of places.

When one is not afraid of the trouble involved in intimately mixing with fat the finely divided carbon obtained in lamp black or Frankfort black, this mixture, when incorporated with the other ingredients, will form shoe polishes of unimpeachable colour, that not only do not corrode the leather but actually preserve it, owing to the presence of the fatty constituents.

Good bone black, ivory black (*Ebur ustum*), and Frankfort black fetch such high prices in commerce that it is far cheaper to prepare them oneself according to the methods about to be described, in which event they will cost only a fraction of their ordinary selling prices.

CHAPTER XXVI.

THE PREPARATION OF BONE BLACK.

THIS fine black pigment, also known as Paris black, is prepared by crushing bones (preferably those of calves or other young animals) into lumps the size of a nut, and placing these fragments in an old cast-iron retort or pot with a close-fitting lid. This vessel is then placed in a furnace in such a manner that it is surrounded on all sides by glowing coals.

Under the influence of the heat the organic substances in the bones soon begin to decompose, the gases liberated burning with a bright flame round the edges of the lid. Heating is continued so long as the gases come off abundantly, but as soon as these cease, or the flame becomes dull and blue, instead of brilliant and white, the operation is complete, whereupon the retort is taken out of the fire and allowed to cool with the lid on.

A still better method is to enclose the bones in an iron wire cage that fits the retort exactly. As soon as the carbonisation is terminated, the cage is taken out, its contents discharged into a tub of water, and the cage is filled with a fresh charge of bones and returned to the retort. By working in this way a considerable quantity of bones can be carbonised in a day in a small furnace.

The glowing bones, quenched by the water, should be light, porous, and of a pure black colour. If heavy, dense, and brown, they have been removed from the furnace too soon; whilst if light, but greyish, especially in the upper layers, they are over-burned, and air has gained access to the interior of the retort.

As already mentioned, access of air must be entirely prevented, otherwise the carbon in the bones will be consumed, and nothing will be left but the white porous bone ash. If

the preparation of this latter product be desired, all that is needed is to place unbroken bones on a brightly burning fire, which may, in fact, be fed with them. They will then burn perfectly white, without, however, losing their shape; and when cold they will furnish perfectly white, porous masses, easily reducible to fine powder.

The quenched burned bones from the above carbonising process are allowed to dry superficially, and are then powdered in a ball mill or between millstones. It is not advisable to let them become perfectly dry before grinding, as this renders the pulverising a troublesome operation, a good deal of the powder also being lost in the form of dust.

The resulting powder can be used direct, but when desired to be particularly fine it is put through a sifting reel which allows the finer particles to pass through, while the coarser particles pass out at the end and are taken back to be reground. The coarser particles in the first vessel are ground over again.

The sifted black is a very handsome product, highly suitable for fine shoe polishes; but if desired for the preparation of fine leather varnishes, it can advantageously be put through a simple refining process, which purifies it still further at little expense, and converts it into so-called ivory black.

Ivory Black. Commercial ivory black is usually nearly pure carbon, obtained by treating moist, levigated bone black with crude hydrochloric acid, the quantity of acid generally used being equal to the original weight of bones calcined.

The hydrochloric acid dissolves the carbonates of lime and magnesia present in the black with effervescence owing to the escape of carbonic acid and also the calcium phosphate comprising the bulk of the bone ash, leaving the carbon unaltered. The mass is stirred up repeatedly during the day, so as to ensure complete solution of the salts, and is then diluted with sufficient water to enable the carbon to settle down, the sediment of carbon being repeatedly washed with water and finally dried.

The ivory black thus obtained forms an extremely fine powder, of a pure black colour, that is used for the finest

lacquer varnishes and can also be employed alone as an artist's colour.

The Preparation of Frankfort Black.—Frankfort black is prepared in a similar manner by carbonising vine twigs, the prunings being usually employed for this purpose. The operation of carbonising can be performed in a wrought iron retort provided with an opening at the upper end for filling and an opening at the lower end for discharging the charcoal, both of these being closed with lids during the heating; also it is provided with a pipe for conveying the volatile products to the fireplace where they are burnt. Heating is continued so long as inflammable gases are liberated from the mass.

The carbonised mass is quenched in water containing 10 per cent. of hydrochloric or sulphuric acid, and is left to stand over night. The acid liquor dissolves out salts that are insoluble in water alone, the residual carbon, when powdered and levigated, furnishing a very beautiful black.

CHAPTER XXVII.

BLACKING AND SHOE POLISHES.

The preparations used for polishing boots and shoes may be subdivided into several classes, generally known respectively as blacking, boot varnish, and leather greases.

Blackings are mixed with water, applied to the leather, and brushed until a polish appears.

Boot varnishes are sold in a liquid form, and are applied to the leather with a brush, whereupon they dry with a bright gloss in a short time.

Leather greases are either semi-solid or oily masses, not intended to give a brilliant polish to leather but to render it soft and supple, and protect it against penetration by water.

Glycerin. Blacking is generally sold in the form of a mass with the consistency of butter, and is best kept in tins, since if packed in boxes or cardboard it dries up when stored for some time, cracks, and loses its fine black colour, so that the saving effected in the method of packing is counteracted by this drawback. An addition of glycerin, however, to the mass will impart the valuable property of remaining soft and glossy, even after prolonged storage.

Blacking containing glycerin can be made up into rolls and wrapped in wax paper. In fact, the addition of glycerin confers such great advantages that it should never be omitted; it keeps the blacking soft for an indefinite period, facilitates its distribution in water, and prevents the usual tendency of blacking to become mouldy.

At the same time it assists the blacking to preserve the leather, by rendering the latter very supple. Shoe leather that is constantly polished with glycerin blacking will never crack.

Pure glycerin is not necessary in the preparation of blacking, the crude brown glycerin, obtainable from candle works at a low figure, being quite suitable.

A large number of blackings present the defect of yielding a polish only after they have been brushed for a long time. This can be remedied by rubbing a little fat on the leather before applying the blacking, or else by mixing a little oil (refined fish oil for choice) with the blacking itself.

With regard to the consistency of blacking, different users vary in their ideas on this point, some preferring a semi-fluid preparation, whilst others prefer it to be very solid. The consistency can be easily modified from one extreme to the other by suitably varying the proportions of fish oil and water.

Since it is to the maker's advantage to sell blacking as soft as possible, the following recipes have been compiled with a view to yielding this class of product. The finished product may, however, be thickened if desired, either by increasing the proportion of bone black or by evaporation. The former method is the cheaper, but the second gives very fine and uniform products.

The concentration of the blacking by the aid of heat is highly recommended when the preparation of very fine grades is in question. Flat, enamelled pans are used, and the mass is kept stirred, since otherwise it is liable to burn and acquire a very disagreeable smell.

Vienna Oil Blacking:—

Bone black	10
Syrup	10
Sulphuric acid	5
Fish oil	20
Water	4
Soda	2

This blacking, excellent in all respects, is prepared in the following manner: The bone black, acid, and syrup are agitated together in a lead-lined iron vessel, until the mass is uniform and exhibits a glossy black surface when left at rest.

The soda is dissolved in a little water, and is boiled with the fish oil in a pan, with constant stirring, until a thick

mass is obtained, with which the first-named mixture is incorporated by stirring.

By increasing or reducing the proportion of the oil to that of the black and syrup, the consistency of the blacking can be modified from thin and soft to hard and solid. The preparation, sold as Paris blacking and under other names, is compounded in the same manner as the foregoing.

In this, as in all other blackings prepared with sulphuric acid and bone black, the mass must be vigorously stirred as soon as the acid has been added and the latter run in in small quantities at a time, otherwise it will become lumpy, and the product will have an undesirable granular structure, whereas good blacking should always be soft, fine, and uniform when applied to the leather.

Black Polish in Sticks:—

Tallow	10 parts
Yellow wax	10 "
Oil of turpentine	5 "

These are melted together and stirred with a previously prepared mixture of 5 parts of fine black and 10 of olive oil. The fluid mass is cast into sticks. In use a stick is rubbed against the leather, which is then polished with a woollen rag.

Lions Blacking.—This French preparation is distinguished by its property of producing a beautiful black polish on leather without injuring the quality of the latter, whilst at the same time its prolonged use renders the leather nearly waterproof. On this account the article deserves close attention, especially since it can be produced cheaply. The following recipe will furnish an article of the highest quality:—

1. Soap	20
Starch	10
Gallnuts	10
Green vitriol	10
Water	2000
2. Syrup	60
Bone black	30

The substances grouped under 1 are boiled together for an hour, then strained through a linen cloth, and stirred carefully with the remaining ingredients whilst still warm.

Hanoverian Blacking :—

1. Bone black	18
Syrup	9
Sulphuric acid	4
2. Gallnuts	4
Water	10
Green vitriol	2

The first mixture is prepared by stirring, in the cold, the second one by boiling the gallnuts in water for two hours, straining the decoction, and adding the green vitriol, the two mixtures being subsequently incorporated by stirring.

Berlin Blacking :—

1. Bone black	100
Syrup	50
Sulphuric acid	10
2. Tan bark	200
Water	200
Green vitriol	10

The first mixture is prepared by stirring together; whilst the tan is boiled with the water for two hours, the green vitriol being dissolved in the decoction, and the whole stirred into the other mixture. Occasionally the following addition is made :—

Logwood extract	50
Potassium chromate	$\frac{1}{2}$
Water	50

this being prepared by heating, a noted improvement in the gloss accruing.

Glue Blacking.—Glue is allowed to swell up in water, then melted and mixed with sufficient glycerin to form a highly elastic jelly when cold. With this is mixed sufficient lamp black to yield a deep black coating when spread out thinly on paper. Since this blacking penetrates deeply into the leather, it is applied until no more appears to be taken up, and the leather is then polished with a woollen cloth.

Waterproof Caoutchouc Blacking :—

1. Bone black	40
Syrup	40
Sulphuric acid	10
2. Caoutchouc	4
Linseed oil	10

The first mixture is prepared and allowed to stand for several days. Then the caoutchouc and linseed oil are heated

together, filtered when cold, united with the first mixture, and the whole heated, with constant stirring, until it has become perfectly uniform. The product is of viscous consistency, and when applied several times, renders the leather water-proof.

Wax Shoe Polish:

Yellow wax	50
Oil of turpentine	5
Potash	10

are melted together and treated with

Sugar	10
Water	500

The resulting white mass is stirred with enough lamp black to colour it deep black.

Wax Polish:

1. Beeswax	10
Soda	10
Water	100
2. Bone black	100
Sulphuric acid	2½
Syrup	100
Fish oil	100

This polish, which is endowed with excellent properties, is prepared as follows: The wax is scraped thin and introduced by degrees into the liquor obtained by dissolving the soda in the water, the solution then being boiled until a scum no longer appears on the surface. Meanwhile the bone black, syrup, and acid are well stirred together, the fish oil being added when frothing begins to subside. The two mixtures are next incorporated, and the finished mass is packed in tins whilst still warm.

Spermaceti Polish:

Beeswax	50
Spermaceti	30
Oil of turpentine	350

are melted together and

Asphalt lac	20
Lamp black	10
Prussian blue	10

are stirred into the liquid, the mass being scented, if desired, with 5 parts of nitrobenzol.

Guttapercha Polish:—

1. Guttapercha	20
Olive oil	50
Gum	20
Water	1000
2. Carbonised bones	200
Lamp black	400
Syrup	1500

The guttapercha is cut into small pieces, mixed with the olive oil and heated, with constant stirring, until a uniform mass is produced, into which the gum, dissolved in the water, is then stirred. The second mixture is then prepared by stirring, and united with the still warm No. 1 mixture.

This polish is entirely free from acid, and therefore will never rot the leather. The presence of guttapercha renders the leather almost waterproof after repeated treatment with this blacking.

Patent Leather Staining Preparation.—For some leather goods it is important to have a dull black colour that is not affected by water or other solvents, but remains permanent, a property desired more particularly in the case of belts and straps. Ordinary kinds of blacking, however, do not fulfil this requirement.

It is desirable not only to produce a permanent black stain on such leather goods, but also to treat boots and shoes in the same way, so as to lessen the consumption of blacking necessary to produce a shine, and also to keep the colour permanent, even though the gloss be spoiled, on prolonged exposure to wet.

A black stain may be produced on leather by boiling—

Logwood chips	1
Water	10

together for two hours, filtering the solution, and applying three or four coatings to the leather with a sponge or brush. Before this application, which stains the leather reddish-brown, is dry, it is followed by one of a 1 per cent. solution of potassium chromate, which changes the colour to a handsome blue-black. When the leather is dry, tallow or fish oil is well rubbed in, and blacking may then be used in the ordinary manner.

Lignite Blacking.—Powdered lignite, sieved through bolting cloth, is treated with strong caustic soda lye and

boiled for several hours, at the end of which time the liquor will have a very dark brown colour, whilst the powder has become very delicate and is nearly as handsome in colour as ivory black. The whole liquid is poured into a vessel containing a large volume of water, and is there left to settle, the black powder being collected on a paper filter, dried, and stirred up in suitable proportion with

Fish oil	10
Lard	50

Belgian Blacking.

Potatoes	10
Sulphuric acid	1
Bone black	5
Lard	20
Fish oil	10

The potatoes are pulped, mixed with the sulphuric acid and heated, with constant stirring, in a stoneware or porcelain vessel, until the mass has become dark brown. The bone black is next added, followed by the fat and fish oil, and the whole heated. Vigorous stirring is important. Should the mass prove too stiff, it is thinned by gradual additions of fish oil. Care, however, is needed here to prevent the mass becoming too thin and greasy, in which event a little bone black must be added.

Indigo Blacking. The article usually sold as indigo blacking contains no indigo, and, indeed, the author has found that indigo is of no particular use in blacking. When used, the indigo must be very finely powdered and ground with fat or oil, or employed in the soluble form of indigo carmine. In either case, the resulting product can only be compared disadvantageously with ordinary well-made blacking. It is never a pure and glossy black, but always an indefinite black which polishes with difficulty when brushed.

Moreover, the high price of indigo would preclude its use for such a cheap article as shoe polish. A preparation, with a fine bluish tinge, and at the same time cheaply made, is obtained from the following:

Syrup	6
Sulphuric acid	1
Bone ash	6
Prussian blue	2
Lamp black	4
Fish oil	12
Lard	8

The sulphuric acid is first mixed with the bone ash, then with the syrup and lamp black, and finally the other ingredients are incorporated.

Glycerin Blacking.—Good blacking should remain soft like butter, even when kept for several years, and should be easily removable from the package and mixed with water. Many otherwise good blackings, however, are liable to dry and crack when they have been packed in wooden or cardboard boxes. Sometimes they set quite hard, and are then difficult to soften with water.

This defect can, however, be cured by mixing the finished blacking with a little glycerin (3 to 4 per cent. being sufficient) before it is packed for sale.

Glycerin is a substance of oily consistency which is very hygroscopic, so that it keeps the blacking constantly moist. It also possesses the valuable property—already alluded to—of rendering the leather soft and supple, besides keeping it free from mouldiness. On this account it forms a useful adjunct to leather-softening preparations, as it is miscible with both fat and water in any proportion.

Liquid Blacking:—

1. Bone black	120
Olive oil	30
Syrup	60
Sulphuric acid	30

These products are mixed, the black being first rubbed down in the oil, the syrup stirred in next, and the acid last.

2. Gum arabic	30
Grape sugar	30
Water	500

The gum and sugar are dissolved in the warmed water, and the solution is gradually mixed with the first mixture. The finished article is filled into bottles.

Lowy's Blacking:—

Powdered gallnuts	100
Logwood extract	4
Vinegar	2500

These substances are boiled for half an hour and strained, the liquid portion being treated with 300 parts of green vitriol and left for twenty-four hours. The clear portion is then drawn off and warmed with—

Gum	25
Sugar	500
Syrup	500

until these substances are dissolved. The liquid is treated with

Spirit of wine	500
Shellac solution	100
Tannin	15

This blacking is liquid, and must be stored in bottles. The shellac solution is prepared by dissolving as much shellac in very strong spirit as the latter will take up.

In the original recipe an addition of 120 parts of powdered indigo is recommended; but this ingredient is now omitted, since it does not improve the quality of the product and adds considerably to the cost.

Iron Blacking:

Bone black	12
Syrup	50
Sugar	5
Fish oil	6
Sulphuric acid	2

These are stirred together until a uniform mixture is obtained, the following being then added:

Tan decoction	5
Green vitriol solution	6
Bone black	30
Sulphuric acid	4
Paris blue	4

Ferrocyanide Blacking:

1. Potassium ferrocyanide	35
Water	5000
2. Green vitriol	100
Water	1000
Nitric acid	15

Solution No. 2 is poured into No. 1 so long as a precipitate forms. Of the wet precipitate, 2000 parts are taken and mixed with

Bone black	1000
Fish oil	1000
Syrup	5000
Water	5000
Sulphuric acid	500

When ultimately mixed, the mass is packed in boxes.

CHAPTER XXVIII

LEATHER VARNISHES.

LEATHER varnishes are merely ordinary varnishes, carefully prepared and stained black. Good leather varnish should dry rapidly, and be specially characterised by elasticity. It should not crack or break, even when the leather is bent strongly and sharply; and it should either be glossy *per se*, or take a fine gloss when rubbed with a flannel or other soft cloth.

The leather varnishes may be divided into two classes, according to the method of preparation: spirit varnishes and oil varnishes. The former contain various substances dissolved in alcohol, and as they dry hard very quickly on being applied, they must be kept in tightly closed bottles.

The oil varnishes prepared with linseed or other oil usually take twelve to twenty-four hours to dry, and then furnish coatings distinguished by fine gloss, durability, and great elasticity.

When it is desired to apply several coatings of leather varnish in succession, each coating must be allowed to become perfectly dry before the next is applied; otherwise uneven surfaces will result.

GLOSSY VARNISHES—

Glossy Black Leather Varnish:—

Boiled oil	.	.	.	.	.	.	.	.	200
Powdered umber	.	.	.	.	.	.	.	.	40
Asphaltum	.	.	.	.	.	.	.	.	80
Oil of turpentine	.	.	.	.	.	.	.	.	200

The boiled (linseed) oil is heated somewhat strongly in an iron pan, along with the umber and asphaltum, and stirred until all is dissolved, the mass is then removed from the source of heat, cooled somewhat and the turpentine then stirred in. The varnish should be fairly viscous. On leather

it forms, in a few hours, a fine glossy coating of great durability.

Antacid Boot Leather Varnish. As the name implies, this preparation is free from acid. It forms a kind of stain, containing the necessary adhesive substances to enable it to adhere properly to the leather. It is prepared as follows:

Powdered galls	50
Logwood	30
Water	2000

These are boiled for two hours, filtered, and

Syrup	200
Green vitriol	30

are dissolved in the liquid, which is next boiled until it commences to thicken, whereupon a solution of

Ruby shellac	1
Alcohol	50

is added and well stirred in, the liquid product being then filled into bottles.

Black Leather Varnish:

Caoutchouc	100
Petroleum	100
Carbon disulphide	100
Shellac	100
Bone black	200
Alcohol	2000

The caoutchouc and carbon disulphide are placed in a well-stoppered flask and left to stand for several days. As soon as the caoutchouc has swollen up, the petroleum is added, with the spirit, followed by the finely powdered shellac, the whole being warmed to about 122° F. As soon as the liquid seems fairly clear, indicating that all the substances are dissolved, the bone black is added, with vigorous shaking, and the varnish is immediately filled into bottles, which are tightly closed.

This varnish dries rapidly, and forms a smooth, fairly elastic, deep black coating on leather.

Harness Varnish:

Brown shellac	50
Venice turpentine	100
Alcohol	1000
Lavender oil	50
Lamp black	30

Black Harness Varnish:—

Shellac	24
Sandarach	4
Elemi	4
Venice turpentine	16
Oil of turpentine	12
Alcohol	1000
Lamp black	40

The resins and turpentine are mixed with the oil of turpentine and heated to boiling, the alcohol being stirred into the cooled mass, followed by the lamp black.

Black Varnish for Belts:—

Shellac	100
Pine resin	20
Venice turpentine	50
Oil of turpentine	40
Alcohol	1000
Lamp black	40

When applied to belts, this varnish, which is fairly elastic, soon forms a fine uniform coating, which dries rapidly, and does not easily crack, even when the leather is strongly bent. For this reason it is very useful for boot leather.

Elastic Leather Varnish (Flexible Blue Varnish).—This varnish, which has a beautiful blue gloss, is extremely flexible and very durable, is prepared in the following manner:

Prussian blue is boiled with linseed oil, the blue being powdered, dried, and introduced into an iron pan containing the heated oil. The proportions are:—

Linseed oil	1000
Boiled linseed oil	100
Prussian blue	200

When the blue has been stirred in, the mass is quickly heated to such a high temperature that the linseed oil commences to evolve fumes, and sometimes takes fire. In view of the latter contingency, which is undesirable, a sheet-iron cover is held in readiness to place on the pan for the purpose of extinguishing the flame.

This operation of boiling the Prussian blue and oil together is accompanied by certain chemical reactions, which have not yet been closely investigated; the linseed oil turns dark brown to black, and thickens. To prevent the blue from settling down, the liquid is repeatedly stirred.

After boiling for several hours—three to four being

generally sufficient—the mass is left to stand at about the boiling temperature of water. The undissolved portion of the Prussian blue sinks to the bottom, leaving the liquid clear, but so dark in colour that it appears black, even in thin layers. It is poured into bottles immediately.

To obtain successful results in this process, the following points should be observed :

Only the finest grade of Prussian blue should be used, the commercial name for this quality being Paris blue. The value of a sample of this blue may be estimated by its great weight, and by the peculiar bronze lustre on the surface of fracture when a lump is broken across.

The lighter coloured "Berlin blue," which lacks the metallic lustre, often contains only 30 per cent., or even less, of the real blue. It is highly important that the blue should be thoroughly dry, since only when this is the case is the operation successful.

The varnish should always be boiled in a pot containing the residual blue from a previous operation, since this enables the residue to be utilised.

To apply this excellent varnish to leather (which latter must not have been previously blacked or polished), a suitable quantity of the varnish is warmed in a pan until fairly thin, and then laid on the leather hot. The resulting coating is a deep blue-black, which dries over night and will stand the action of the weather perfectly. The leather can be bent to any extent without injury.

CAOUTCHOUC VARNISH—

Ordinary Caoutchouc Varnish:

Caoutchouc	10
Petroleum	20
Oil of turpentine	10
Boiled linseed oil	500

The caoutchouc is first dissolved by warming with the petroleum and oil of turpentine, the boiled oil being added next. If the varnish is to be black, 50 parts of fine lamp black are stirred in.

Elastic Caoutchouc Varnish:

Refined pine resin	10
Oil of turpentine	5
Caoutchouc	5
Linseed oil	10

The pine resin and oil of turpentine are melted together, the caoutchouc and linseed oil being then added, and the whole stirred until a uniform mixture is produced. When applied to leather this varnish will long remain elastic, even in the cold; without cracking.

Caoutchouc Varnish for Rubber Shoes:—

Caoutchouc	70
Refined pine resin	140
Oil of turpentine	250
Bone black	20

The caoutchouc and oil of turpentine are heated together somewhat strongly, the resin being then melted in the solution and the bone black stirred into the hot mass.

Caoutchouc Repairing Varnish:—

Caoutchouc	10
Benzol	70

The caoutchouc and benzol are placed in a carefully closed flask, which is exposed to sunlight until solution is complete. This varnish is highly suitable for repairing worn rubber shoes and waterproof coats. The damaged parts are painted over with the varnish, the edges of cracks being pressed together and held for a few minutes in that position.

Asphaltum Varnish.—Syrian asphaltum (bitumen) is a substance very insusceptible to the action of chemicals, and is distinguished by a handsome black colour, both of which properties render it extremely suitable for use in varnishes for leather, wood, metals, etc. A varnish suitable for all purposes can be obtained by shaking up the finest Syrian asphaltum in a flask with rectified oil of turpentine, the two being left in contact until complete solution can be assumed to have occurred. The flask is left to stand for a week longer, to enable any undissolved matter to settle down, the supernatant liquid being afterwards poured off from the sediment. If necessary, the solution can be thinned with oil of turpentine: the thinner the coating on the leather, the higher the gloss.

Liquid Asphaltum Glossy Varnish:—

Syrian asphaltum	10
Oil of turpentine	10
Petroleum	10

are placed in a closed flask and left to stand for several days, with repeated shaking. Meanwhile

Tamp black	:	:	:	:	:	:	:	:	1
Linseed oil	:	:	:	:	:	:	:	:	5

are rubbed down together, and then incorporated with the asphaltum solution by stirring. The finished varnish must be filled into tightly closed bottles.

CHAPTER XXIX.

LEATHER SOFTENING PREPARATIONS.

THESE preparations are used for the purpose of preserving the leather, rendering it soft and flexible, and preventing the penetration of water. Those that are fluid and of an oily nature, are simply rubbed into the leather with the hand or a woollen cloth, whilst the more solid ones must first be liquefied by heat.

In all circumstances it is advisable to use these preparations, whether liquid or solid, slightly warm, since in this condition they penetrate much deeper into the leather than when used at the ordinary temperature.

After the first application, it is advisable to put the leather in a warm place, until the gloss produced by the preparation has disappeared, *i.e.* till the preparation has been fully absorbed by the leather.

It is a widespread error that wet leather cannot be greased, but ought first to be thoroughly dried. This is incorrect; besides, the leather becomes hard and brittle on drying, and then requires a long time to resoften by the aid of greases.

Wet leather, on the other hand, is in a very suitable condition for greasing, all that is necessary being to wipe it over with a dry cloth until the grease will adhere, and then to rub the latter well in. Drying can be conducted at the ordinary temperature, or with the aid of heat, without the leather becoming hard or brittle; so that under these conditions it fully retains its flexibility and softness.

Soap Grease for Boot Uppers.—One hundred parts of soap are dissolved in 1000 of water, and 100 parts of glycerin, 25 of beef tallow, 25 of fish oil, and finally 25 parts of

colophony are added. The whole is boiled for some time, and then stirred until cold.

Harness Grease:

Soap	2
Sugar	2
Water	4
Potash	1
Rape oil	20

The solids are dissolved in the water, and stirred with the rape oil, being kept warm, until a uniform mixture is obtained.

Glossy Waterproof Grease:

Wax	1
Soap	1
Lamp black	3
Oil of turpentine	5
Fish oil	20

The wax is dissolved in the oil of turpentine by the aid of heat, the soap is scraped and added, followed by the fish oil, and finally by the lamp black.

Waterproof Leather Grease:

Oleic acid	24
Crude stearic acid	6
Ammonia soap	18
Tannin extract	3
Water	24

The oleic acid and crude stearic acid are melted together, the ammonia soap being then added by degrees, followed by the tannin extract, and finally by the water.

The ammonia soap is produced by adding ammonia to hot oleic acid, until the smell of ammonia is perceptible after prolonged stirring, and the whole has set to a jelly.

By adding to this grease a solution of 2 parts of green vitriol in 6 of water, it is stained a deep black, and is then admirably adapted for application to shoe leather.

Waterproof Leather Grease:

Wax	30
Asphaltum	10
Oil of turpentine	50
Linseed oil	100
Olive oil	100

The wax and asphaltum are dissolved in the warmed oil of turpentine; and the olive oil and linseed oil, having been heated together, are poured into the solution, the whole being made homogeneous by stirring.

Gloss for Greased Leather:—

1. Ruby shellac	2
Alcohol (95 per cent.)	10

The shellac is dissolved, in the course of a few days, by repeatedly shaking it up in the spirit, in a bottle that is stored in a warm place.

2. Marseilles soap	25
Alcohol (95 per cent.)	400
Glycerin	40

The Marseilles soap is dissolved in the alcohol and the glycerin added, this is then united with the first solution and the whole mixed with a solution of 5 parts of nigrosine in 120 of spirit. This addition gives the gloss a beautiful black colour.

Fish Oil Leather Grease.—Fish oil—in itself an excellent softener for leather—is, in many cases, precluded from use by its highly disagreeable smell. To remove this defect and enable the oil to penetrate readily into the leather, the oil is stirred up with a solution of tannin, until the smell has disappeared and the entire mass has assumed the consistency of butter.

It is then left to stand, the fat is separated from the watery portion, and is then treated with a very small quantity of carbolic acid, which preserves the refined oil from becoming rancid in storage. The proportions used are:—

Fish oil	100
Tannin	2
Water	10
Carbolic acid	50

Grease for Wading Boots:—

Spermaceti	20
Wax	40
Pine resin	30
Turpentine	50
Linseed oil	400
Fish oil	200

The wax, spermaceti, and pine resin are melted together, the turpentine being then added, followed by the linseed oil and fish oil, the whole being heated to the boiling point of water and stirred for half an hour.

Resin Grease for Leather:—

Pine resin	10
Oil of turpentine	3
Lard	30

The resin is dissolved in the oil of turpentine by the aid of heat, the lard being then added, and the whole mixed to a uniform mass by continued stirring, after which it is left to cool. When endeavours are made to expel the oil of turpentine by protracted heating, this can only be done without injury to the product, provided the temperature employed does not exceed about 356° F., at which temperature the oil of turpentine will vaporise very quickly without the fat being affected. Any higher temperature, however, partly decomposes the fat, and forms products that would injure the leather.

For leather subjected to frequent bending, this grease is unsuitable, but it is very useful for harness, belts, etc.

Caoutchouc Grease:

Caoutchouc	8
Oil of turpentine	.	.	.	.	.	.	.	.	8
Lard	.	.	.	.	.	.	.	.	10
Fish oil	.	.	.	.	.	.	.	.	50
Tallow	.	.	.	.	.	.	.	.	10
Lamp black	.	.	.	.	.	.	.	.	2

The caoutchouc is dissolved in the heated oil of turpentine, and the filtered solution is poured into the melted fat, which has previously been stirred with the lamp black.

Patent Caoutchouc Grease:

Caoutchouc	.	.	.	.	.	.	.	.	1
Oil of turpentine	.	.	.	.	.	.	.	.	5
Brown sugar	.	.	.	.	.	.	.	.	40
Sulphuric acid	.	.	.	.	.	.	.	.	5
Rape oil	.	.	.	.	.	.	.	.	40
Bone black	.	.	.	.	.	.	.	.	8

The caoutchouc is dissolved in the oil of turpentine, the sugar and bone black are treated with the sulphuric acid with the aid of heat for several hours; the two mixtures are united, mixed with the rape oil, and heated for an hour.

Petroleum Jelly as a Grease and Preservative.—Petroleum jelly is an exceedingly valuable emollient for all kinds of leather, since the very hardest leather can be softened by repeatedly rubbing in this jelly till it will absorb no more. At the same time the leather thus treated offers greater resistance to the penetration of moisture, and is preserved from becoming brittle.

Petroleum Jelly Grease for Leather.—Petroleum jelly can

be used on natural leather by itself, but for black leather the following composition is recommended:—

Petroleum jelly	.	.	.	.	.	.	.	.	100
Lamp black	.	.	.	.	.	.	.	.	5
Prussian blue	.	.	.	.	.	.	.	.	5

A small portion of the petroleum jelly is melted in an enamelled iron pan, the lamp black and Prussian blue being added, and stirred until the mass is uniform. The rest of the petroleum jelly is afterwards stirred in by degrees.

CHAPTER XXX.

THE MANUFACTURE OF DÉGRAS.

THE product known as dégras, or tanner's grease, is distinguished by its property of penetrating leather with great ease, and imparting to it extreme softness and suppleness. Hence, when it is desired to make hard leather soft and flexible, dégras forms the best material for effecting the purpose in view.

Before the properties of the fats had been more closely investigated, dégras was prepared in a very peculiar manner, owing to which circumstance it was only obtainable in small quantities commercially, and was high in price. Even now that it can be produced in any quantity, the price is still comparatively high, so that the process is a very profitable one.

Dégras is really fat in a state of emulsion, *i.e.* fat distributed very finely in a liquid of suitable character, so as to form a mass of the consistency of ointment or butter.

The characteristic feature of good dégras is that it is very readily absorbed by leather to which it is applied, and such leather no longer heats when piled up in heaps, but in a short time appears to be uniformly impregnated with the mass.

Production of Dégras as a By-Product in Making Shamoy Leather.—In the manufacture of shamoy leather the suitably prepared skins are sprayed with fish oil and thrown into heaps. Owing to the incipient oxidation of the fat the heaps soon become rather hot; and after a certain time the skins are put through a fulling process, and finally treated with a 10 per cent. solution of potash. A milky white liquid is thus formed in which the fat is found to be distributed in the form of exceedingly fine globules.

This liquid is treated with sufficient sulphuric acid to neutralise the potash, whereupon the fat collects on the surface, in the form of a dirty white or yellow to brown mass, of

rather mild flavour, and specially adapted for softening tanned leather, which absorbs it greedily.

In many works, skins are shamoyed for the special purpose of producing dégras, that is to say, after being fulled and treated with potash, the skins are resoaked with fish oil, left to heat, fulled, and treated again with potash, this cycle of operations being repeated until the skins drop to pieces.

Production of Dégras from Fish Oil.—A much simpler method of producing dégras, however, is by emulsifying fish oil in the following manner: A solution of potash (10 to 20 per cent. strength) is boiled in a capacious pan, and fish oil is run into the hot liquor, in the form of a very thin stream, from a tank overhead, the liquid being kept stirred by means of paddles, etc. The quantity of fish oil used must be determined in each case. With some fish oils as much as 50 per cent. of the mass in the pan may be taken, but in others a much smaller proportion is sufficient.

After all the fish oil is in, the stirring is continued for a considerable time, and the mass is heated further, samples being drawn at intervals. When one of these samples no longer separates into two layers on being left to stand for some time in a high test-glass, but forms a homogeneous milky liquid, the operation is complete. The finished dégras is then stirred whilst cooling, until it becomes viscous, whereupon it is poured into barrels.

In the majority of cases the above procedure will give very favourable results, yielding a product fulfilling all requirements. With some kinds of fish oil, however, all attempts to produce a good dégras are in vain. The heating and stirring may, for example, be continued for hours, but the resulting mass will give up a large proportion of its fat on standing. Hence one is forced to conclude that certain kinds of fish oil are incapable of forming an emulsion with potash solution. It is therefore always advisable to test the suitability of the fish oil by treating a small quantity with potash solution in an enamelled pan, with constant stirring.

Fish oil that will not thoroughly emulsify with potash solution may be made to do so by first heating some weak caustic soda in the pan, and stirring the oil with this until it

grows milky, which done, a very strong solution of potash can be added, and stirring continued so long as a drop of fat can be detected in the liquid, whereupon the already mentioned test is applied.

The *modus operandi* is as follows: A 1 per cent. solution of caustic soda is prepared by dissolving drum soda in the pan; and the fish oil and potash solution are stored in two overhead tanks fitted with taps. The potash solution, it may be stated, is prepared by mixing potash and water in equal amounts, and stirring them, at frequent intervals, during twenty-four hours, at the end of which time the solution is poured off from any undissolved residue and transferred to the tank aforesaid.

The soda lye having been heated to boiling, the tap of the oil tank is opened sufficiently to allow a stream of oil, about the thickness of a pencil, to run into the pan, the contents of which are kept well stirred the whole time. When all the oil is in and the liquid has become milky, the potash solution is also run in as a thin stream, and the whole stirred until a satisfactory sample is obtained.

To produce a yield of greater consistency, a somewhat larger proportion of caustic soda must be taken, the solution being made of $1\frac{1}{2}$ to 2 per cent. strength in place of 1 per cent. The exact amount, however, must be ascertained by a preliminary experiment, since an excess would give a product more like soap than ointment. The *dégras* should be of such consistency that it can be easily applied to leather with the finger and be rapidly absorbed by the material.

Olein Dégras.—Olein or oleic acid, the by-product from stearine candle works, can be very advantageously employed in the preparation of a very useful *dégras*, though one inferior to that obtained from fish oil. The method of preparation is the same as for fish oil *dégras*, the olein being run into the boiling caustic soda lye; but the milky stage is generally reached more quickly.

If the quickly cooled sample shows the finished product to be too fluid, a corresponding quantity of olein soap is added to the hot mass in the pan. To enable this soap to dissolve rapidly and completely, it must be cut into

fine shreds and stirred until not the slightest white fragment of undissolved soap can be seen in samples taken from time to time, the latter being quite homogeneous.

Some practical men look upon brown dégras as being stronger than that of lighter colour—an opinion that is devoid of foundation, the colour being derived solely from the use of some dark fish oil in the manufacturing process.

However, the desire of consumers to have a dark-coloured dégras can be easily gratified by suitably colouring the contents of the pan whilst still hot. The best means for effecting this is to add a very strong decoction of tan or tannin extract. This solution is poured into the dégras as a thin stream, and stirred until the whole mass has acquired an even colour. In this case also it is desirable for the buttery consistency to be retained. When a good sample of dégras is spread thickly on a sheet of glass and held up to the light, it should have a uniformly translucent appearance, without exhibiting lighter or darker patches.

Black Dégras.—This product is obtained by stirring dégras up with tan or tannin extract, and then, whilst still hot, adding a small quantity of green vitriol solution, followed by protracted stirring. The whole mass quickly stains a deep black, and the product is highly suitable for greasing black leather, which is desired to be supple, and not to become hard and brittle when wet.

Dégras from Waste Fat.—By suitable treatment, any fat that is almost unfit for other purposes, owing to the presence of impurities, can be converted into dégras. Thus, a useful and profitable dégras is obtained from the dark and evil-smelling fat recovered by boiling bones in an advanced state of decomposition. For this purpose the fat is heated to 250° to 265° F. in a pan for half an hour with constant stirring. A very disagreeable smell is given off, and the contents of the pan are next stirred up with 1 to 5 per cent. of $\frac{1}{2}$ per cent. soda solution, followed by the potash as already described. In this way, and without any soap for thickening, a brown dégras is generally obtained that will do all that can be reasonably expected of it.



INDEX.

Acid liquor in resin still, 79.

Acids—

Arachidic, formula, melting point, and origin of, 14.
 Behenic, formula, melting point, and origin of, 14.
 Brassidic, formula, melting point, and origin of, 14.
 Butyric, 146.
 Butyric, formula, melting point, and origin of, 14.
 Capric, formula, melting point, and origin of, 14.
 Caproic, formula, melting point, and origin of, 14.
 Caprylic, formula, melting point, and origin of, 14.
 Carbolie, in leather softeners, 228.
 Cerotic, formula, melting point, and origin of, 14.
 Cinnamic, 146.
 Doeglic, formula, melting point, and origin of, 14.
 Elaeomargaric, formula, melting point, 15.
 Erucic, formula, melting point, and origin of, 14.
 Fatty, 12, 13, 14, 15, 22, 23, 24, 38, 40, 48, 50, 104, 126, 148.
 Gadoleic, formula, melting point, and origin of, 14.
 Hydroxy (Table 5), 15.
 Hypogoeic, formula, melting point, and origin of, 14.
 Isocetic, formula, melting point, and origin of, 14.
 Isolinolenic, formula, melting point, and origin of, 15.
 Jecoleic, formula, melting point, and origin of, 14.
 Lauric, formula, melting point, and origin of, 14.
 Lignoceric (carnaubic), formula, melting point, and origin of, 14.
 Linolenic, formula, melting point, and origin of, 15.
 Linolenic series, general formula (Table 4), 15.

Acids (*cont.*)—

Linolic, formula, melting point, and origin of, 15.
 Melissic, formula, melting point, and origin of, 14.
 Myristic, formula, melting point, and origin of, 14.
 Naphthenic, 146.
 Nitric, in blacking, 214.
 Oleic, 13, 52, 112, 113, 166, 167, 168.
 Oleic, formula, melting point, and origin of, 14.
 Oleic, in leather softeners, 222.
 Palmitic, 13.
 Palmitic, formula, melting point, and origin of, 14.
 Physctoleic, formula, melting point, and origin of, 14.
 Rapic, formula, melting point, and origin of, 14.
 Ricinoleic, 13.
 Ricinoleic, formula, melting point, and origin of, 15.
 Saturated (Table 1), 14.
 Sodium, salts of the, as emulsifying agents, 155.
 Stearic, formula, melting point, and origin of, 14.
 Stearic, in leather softeners, 222.
 Sulphuric, 156-162, 164, 165.
 Sulphuric, action on oils, 52.
 Sulphuric, in leather softeners, 224.
 Sulphuric, in oil purification, 22.
 Sulphuric, process of refining oils 22, 23, 24, 25, 26, 29, 31.
 Tiglic, formula, melting point, and origin of, 14.
 Unsaturated (oleic series), (Table 2), 14.
 Unsaturated (linolic series), (Table 3), 15.
 Valeric, formula, melting point, and origin of, 14.
 Aerostatic oil can, 180, 181.
 Albumin in lubricants, 138.
 Alcohols—
 Ceryl, formula, melting point, and origin of, 15.

- Alcohols (*cont.*)
 Cetyl, formula, melting point, and origin of, 15.
 For purifying rape oil, 152.
 In fats and waxes in free state, 16.
 In fats and waxes, with fatty acids, 15.
 In leather softeners, 223.
 In leather varnish, 216, 217.
 Monovalent aromatic (sterols), (Table 3), 16.
 Monovalent, of the fatty series (Table 2), 15.
 Myricyl, formula, melting point, and origin of, 15.
 Octodecyl, formula, melting point, of the fatty series, 16.
 Purifying oil with, 149.
 Trivalent (Table 1), 15.
 Aldehydes, 13.
 Almond oil as a lubricant, 45, 46, 149, 153.
 Almond oil, specific gravity of, 45, 46.
 Alumina soaps, 90.
 American machine oils and greases, 137.
 American palm oil greases, 109.
 Ammonia, 52, 96.
 Ammonia in emulsion lubricants, 96.
 Ammonia soap in leather softeners, 222.
 Analyses of sulphuretted oils, 174-176.
 Animal and vegetable oils, surface tension of, 146.
 Animal fats, 47.
 Animal fats and oils in lubricants, 8.
 Antacid boot-leather varnish, 216.
 Anthracene oils, 71.
 Anti-friction greases, 111.
 Arachidic acid, formula, melting point, and origin of, 14.
 Arachis oil, 32.
 Asphalt lac in blacking, 210.
 Asphaltic residue in rosin, 79.
 Asphaltum axle grease, 119.
 Asphaltum in black varnishes, 83.
 Asphaltum in leather softeners, 222.
 Asphaltum in leather varnish, 215, 219.
 Asphaltum, specific gravity of, 83.
 Asphaltum varnish, 219.
 Australene, specific gravity, etc., of, 66.
 Autumn grease, 107.
 Axle grease—
 Asphaltum, 119.
 Caoutchouc, 117.
 English patent, 135.
 Graphite, 120.
 Quick-running, 112, 134.
 Rosin oil, 130.
 Axle greases, 98, 99, 100, 101, 102, 103, 106, 111, 112, 115, 131.
 Axle greases for different seasons, 106, 107, 108, 109.
 Axle greases for heavy waggons, 109.
 Axle greases, lanolin, 141.
 Axles, quick-running, greases for, 112, 113, 120.
 Beechnut oil as lubricant, 32.
 Behenic acid, formula, melting point, and origin of, 14.
 Belgian blacking, 212.
 Belgian cart grease, 135.
 Belgian palm oil greases, 109.
 Belting grease, 131.
 Belting grease, Schueckart's, 138.
 Belt varnish, 217.
 Benzene series of hydrocarbons, 61.
 Benzine, 57, 58, 59, 60, 61, 76.
 Benzine, Burma exports of, 57.
 Benzine, heavy, specific gravity, etc., of, 66.
 Benzine, light, specific gravity, etc., of, 66.
 Benzine, specific gravity, etc., of, 63.
 Benzol for cleaning machinery, 194.
 Benzol for cleaning rags, etc., 195.
 Benzol for refining bone oil, 151.
 Benzol in leather varnish, 219.
 Berlin blacking, 209.
 Berlin blue in leather varnish, 218.
 Bitumen, 55.
 Black, bone, preparation of, 203, 204.
 Black dégras, 229.
 Black, Frankfurt, preparation of, 205.
 Black, ivory, preparing, 204.
 Black lead in lubricants, 89.
 Black leather varnish, 215, 216.
 Black polish in sticks, 208.
 Black varnish for bolts, 217.
 Blacking, 206-214.
 Blacking—
 Asphalt lac in, 210.
 Belgian, 212.
 Berlin, 209.
 Bone ash in, 212.
 Bone black in, 207, 208, 209, 210, 212, 213, 214.
 Caoutchouc in, 209.
 Ferrocyanide, 214.
 Fish oil in, 207, 210, 211, 212, 214.
 Gallnuts in, 208, 209, 213.
 Glac, 209.
 Glycerin, 213.
 Glycerin in, 206, 207, 213.
 Green vitriol in, 208, 209, 214.
 Gum in, 211, 213, 214.
 Gutta-percha in, 211.
 Hanoverian, 209.
 Indigo-carmin in, 212.
 Indigo in, 212, 214.
 Iron, 214.

- Blacking (*cont.*)—
 Lampblack in, 210, 211, 212.
 Lard in, 212.
 Lignite, 211.
 Linseed oil in, 209.
 Liquid, 213.
 Logwood extract in, 209, 213.
 Lowy's, 213.
 Lyons, 208.
 Nitric acid in, 214.
 Olive oil in, 211, 213.
 Paris blue in, 214.
 Potash in, 210.
 Potassium chromate in, 209.
 Potassium ferrocyanide in, 214.
 Potatoes in, 212.
 Prussian blue in, 210, 212.
 Shellac in, 214.
 Soap in, 208.
 Soda in, 207, 210.
 Spermaceti in, 210.
 Spirit in, 214.
 Starch in, 208.
 Sugar in, 210, 213, 214.
 Sulphuric acid in, 207, 209, 210, 212, 213, 214.
 Syrup in, 207-214.
 Tallow in, 208.
 Tan in, 209, 214.
 Tannin in, 214.
 Turpentine oil in, 208, 210.
 Vienna oil, 207.
 Vinegar in, 213.
 Water in, 207, 208, 209, 210, 211, 213, 214.
 Waterproof caoutchouc, 209.
 Wax in, 208, 210.
 Bleaching oil, 149.
 Bleaching powder for refining oil, 152, 153.
 Blown oils, 50, 51.
 Blue patent grease, 136.
 Blue varnish, flexible, 217.
 Boleg's patent for preparation of mineral, rosin, and tar oils soluble in water, 171-173.
 Bone ash in blacking, 212.
 Bone black, 36, 101.
 Bone black in blacking, 207, 208, 209, 210, 212, 213, 214.
 Bone black in leather softeners, 224.
 Bone black in leather varnish, 216, 219.
 Bone black, preparation of, 203, 204.
 Bone fat, 18, 35, 36, 37, 38.
 Bone fat, bleaching, 36, 37.
 Bone fat greases, 101.
 Bone fat, nitro-hydrochloric acid method of refining, 36.
 Bone fat, preparation of, 35, 36, 37, 38.
 Bone fat, purifying, 36.
 Bone fat, specific gravity and melting point of, 38.
 Bone oil, 36, 44.
 Bone oil as a lubricant, 36, 150.
 Bone oil, refining, 150-151.
 Bones, fat from, digester for extracting, 18.
 Bones, recovery of fat from, 36.
 Booth's patent grease, 101.
 Boots, wading, grease for, 223.
 Boot uppers, soap grease for, 221.
 Brassidic acid, formula, melting point, and origin of, 14.
 Butyric acid, 146.
 Butyric acid, formula, melting point, and origin of, 14.
 Caoutchouc, 83, 153.
 Caoutchouc adhesion grease, 117.
 Caoutchouc and fat grease, 117.
 Caoutchouc and gutta-percha grease, 117.
 Caoutchouc axle grease, 117.
 Caoutchouc blacking, waterproof, 209.
 Caoutchouc, varnish, elastic, 218.
 Caoutchouc grease, American, 116.
 Caoutchouc grease, Doulon's, 116.
 Caoutchouc grease for driving belts, 135.
 Caoutchouc grease for leather, 224.
 Caoutchouc in blacking, 209.
 Caoutchouc in leather softeners, 224.
 Caoutchouc in leather varnish, 216, 218, 219.
 Caoutchouc leather varnish, 218.
 Caoutchouc lubricants, 116, 117, 118, 153.
 Caoutchouc machine grease, 116.
 Caoutchouc repairing varnish, 219.
 Caoutchouc varnish, 218.
 Caoutchouc varnish for rubber shoes, 219.
 Capric acid, formula, melting point, and origin of, 14.
 Caproic acid, formula, melting point, and origin of, 14.
 Caprylic acid, formula, melting point, and origin of, 14.
 Caps, grease, 187, 188.
 Carbolic acid in leather softeners, 223.
 Carbolic oils, 71.
 Carbon bisulphide, 18, 20.
 Carbon disulphide in leather varnish, 216.
 Carbon disulphide in lubricating oil, 153.
 Cart greases, 109, 121.
 Castor oil, 13, 47, 49, 50, 52, 165.
 Castor oil, and blown oil, comparison of analytical figures for (Lewkowitsch), 50.
 Castor oil, examination of products obtained by blowing (Proctor and Holmes), 50.

- grease, 138.
 properties of, 47.
 specific gravity of, 47.
 saponated, as emulsifying
 56.
 sh, 13.
 sh in refining oils, 28.
 13.
 conversion of soda crystals
 refining oils with, 27, 28.
 formula, melting point,
 n of, 14.
 ap grease, 114.
 ricants, 7.
 formula, melting point,
 n of, 16.
 l, 146.
 s, filter press for, 22.
 s, settling tank for, 21.
 oils, 149-153.
 f constituents of (Lunge),
 l.
 position of, 67.
 llation of, 70, 71.
 cases, 137.
 71.
 ific gravity, etc., of, 67.
 70, 71.
 ase, 134.
 127-129.
 se, 121.
 i lubricant, 120.
 lubricating oil, 137.
 5, 138, 141.
 leather softeners, 222.
 stor for greases, 135, 136,
 e Rape oil.
 s, 173.
 , 137.
 , blown, table showing
 cleaning, 195, 196.
 storing, 196.
 71.
 ions, 174.
 2, 173.
 ificant tester, Bailey's
 tent, 191, 192.
 142, 143, 144, 145.
 motor, recipes for, 153,
 preparation of, 142.
 specific gravities, etc., of,
 3.
 team engines, deposits
 ir in, 145.
 ling point, etc., of, 63.
 acture of, 226-229.
 ying for, 226, 227.
- Digester for extracting fat from bones,
 18.
 Doeglic acid, formula, melting point,
 and origin of, 14.
 Dolphin oil, specific gravity of, 41.
 Doulon's caoutchouc grease, 116.
 Driving belt grease, 134, 135.
 Drying oils, 10, 49.
 Earthnut oil, specific gravity of, 46.
 Elæomargaric acid, formula, melting
 point, and origin of, 15.
 Elastic caoutchouc varnish, 218.
 Elastic leather varnish, 217, 218.
 Elemi in leather varnish, 217.
 Emulsifiable oils, soluble in water,
 171, 172, 173.
 Emulsifying agents, sodium salts of
 the acids as, 155.
 Emulsion lubricants, 95, 155-176.
 Emulsions, cutting, 174.
 Emulsions, mineral oil, formation of,
 176.
 Emulsions, use of, 104.
 Engine cylinder, "Kirkham" patent
 lubricator, 183, 184, 185.
 Engine, gas, lubricating oil for, 152.
 Erucic acid, formula, melting point,
 and origin of, 14.
 Fat and caoutchouc grease, 117.
 Fat and rosin oil lubricants, 130.
 Fat from bones, digester for extract-
 ing, 18.
 Fat, recovery of, from bones, 36.
 Fat rendering pan, fire-heated, 16.
 Fat solvents, volatile, 18.
 Fat, waste, dégras from, 229.
 Fats and oils, animal, as lubricants,
 8-10.
 Fats and oils, composition of, 11, 12.
 Fats and oils, preparation of, 17.
 Fats and oils, properties of, 33.
 Fats and oils, purification of, 20, 21,
 22, 35.
 Fats and oils, sterols in, 16.
 Fats and oils, vegetable, as lubricants,
 8-10.
 Fats and soda solution, mixture of, 106.
 Fats and waxes, alcohols in, 15.
 Fats as lubricants, 7-10, 11.
 Fats, bone, 18, 35, 36, 37, 38.
 Fats, bone, bleaching of, 36, 37.
 Fats, bone, nitro-hydrochloric acid
 method of refining, 36.
 Fats, bone, preparation of, 35-38.
 Fats—
 Gambier, 137.
 Hog, 35, 44.
 Horse, 39, 108, 113.
 Jacketed mixer for melting, 99.
 Liquid, 9, 10, 103, 106.

Fats (*cont.*)—

- Liquid, as lubricants, 40.
- Neutral, 48.
- Pork, 120.
- Rancidity of, 48.
- Solid, 9, 10, 21, 33.
- Wool, 141, 146.
- Fatty acids, 12, 13, 14, 15, 22, 23, 24, 38, 40, 48, 50, 104, 126, 148.
- Fatty acids and alcohols in fats and waxes, 15.
- Fatty acids, effect of, in reducing friction (table by Archbutt), 148.
- Fatty acids, glycerides of, 12, 13.
- Fatty acids in palm oil, 40.
- Fatty acids in refined oils, 24.
- Fatty acids versus neutral oils in reducing friction, 148.
- Fatty acids, volatile, 50.
- Fatty lubricants, 7-11.
- Fatty oil for clocks, 150.
- Fatty oils, 52, 126.
- Fatty oils, surface tension of, 147.
- Ferrocyanide blacking, 214.
- Filter press for clarifying oils, 22.
- Fish oil, 135, 211.
- Fish oil in blacking, 207, 210, 211, 212, 214.
- Fish oil in leather softeners, 221-224.
- Fish oil, making dégras from, 227, 228.
- Fish oils, blown, table showing results, 51.
- Flexible blue varnish, 217.
- Flexible oil can, 179, 180.
- Fluidity of lubricants, 6.
- Fluidity of oils, measurement of, 143.
- Fractional distillation of mineral oil, 64, 65.
- Fractionation of petroleum oils, 63.
- Frankfort black, preparation of, 205.
- French palm oil greases, 109.
- French tallow grease, 102.
- Frictional resistance and lubrication, 2-5, 11.
- Fuel oil, 54, 58, 59.
- Fuel oils from Russian petroleum, 67.
- Fuel oils, specific gravity, etc., of, 67.
- Gadoleic acid, formula, melting point, and origin of, 14.
- Gallnuts in blacking, 208, 209, 213.
- Gallnuts in leather varnish, 216.
- Gambier fat, 137.
- Gas oil, 57, 58, 77.
- Gas oil, specific gravity, etc., of, 66.
- Gas oils, U.S.A. exports, 54.
- Gasolene, specific gravity, etc., of, 63.
- Globe oil, 140.
- Glossy varnishes, 215, 219.
- Glossy waterproof grease, 222.
- Glue, 36, 101, 116, 117.
- Glue blacking, 209.
- Glycerides of fatty acids, 12.
- Glycerin blacking, 213.
- Glycerin in blacking, 206, 207, 213.
- Glycerin in leather softeners, 221, 223.
- Glycerine, 12, 13, 16, 41, 137.
- Glycerol, formula, melting point, and origin of, 15.
- Goudron from Russian petroleum, 67.
- Goudron, specific gravity, etc., of, 67.
- Graphite, 110.
- Graphite, Acheson, analysis of, 91, 92.
- Graphite, artificial, 90.
- Graphite as a lubricant, 89.
- Graphite axle grease, 120.
- Graphite, deflocculating agent in, 91, 92, 93.
- Graphite in lubricants, 8, 9.
- Graphite lubricant, Drechsler's, 138.
- Graphite mixture, aqueous, 91.
- Grease and oil, removing thickened, 193, 194.
- Grease, Booth's patent, 101.
- Grease boxes, 178, 179.
- Grease caps, 187, 188.
- Grease for fine machinery, 103, 133.
- Grease for wading boots, 223.
- Grease for wooden machinery, 110.
- Grease, spring, 98.
- Grease, spring and autumn, 107.
- Grease, summer, 98, 101, 107, 132.
- Grease, winter, 98, 101, 107.
- Greaser for large shafts, 185, 186.
- Greaser, Reissart spring, 185, 186.
- Greases—
 - American caoutchouc, 116.
 - American machine, 137.
 - American palm oil, 103.
 - Anti-friction, 111.
 - Asphaltum axle, 119.
 - Autumn, 107.
 - Axle, 98, 99, 100, 101, 102, 103, 106, 111, 115, 117, 131, 133, 141.
 - Axle, English patent, 135.
 - Axle, for heavy waggons, 109.
 - Axle, graphite, 120.
 - Axle, quick-running, 112, 113, 120, 129, 134.
 - Axle, rosin oil, 130.
 - Belgian cart, 135.
 - Belgian palm oil, 109.
 - Belting, 134.
 - Belting, Schuckart's, 138.
 - Blue patent, 136.
 - Bone fat, 101.
 - Caoutchouc, 116, 117, 135, 224.
 - Cart, 109, 121.
 - Castor oil, 102.
 - Chardon's, 114.
 - Coconut oil in, 140.
 - Cog-wheel, 134.
 - Colophony in, 138.
 - Colouring matter for, 135, 136, 141.

Greases (*cont.*)—

Doulon's, 116.
 Driving-belt, 134, 135.
 Fat and caoutchouc, 117.
 French palm oil, 109.
 French tallow, 102.
 Glossy waterproof, 222.
 Glue in, 116, 117.
 Graphite, 110, 120.
 Graphite in, 89.
 Harness, 222.
 Horse fat, 113.
 Lanolin, 141.
 Lead oleate, 112, 113.
 Lime in, 96, 131, 132, 135, 140.
 Linseed oil in, 140.
 Litharge in, 117.
 Lye in, 114, 115.
 Machine, 97, 120, 137.
 Magnesia, 140.
 Mineral, 140.
 Mineral oil in, 140.
 Naphthalene, 119.
 Neatsfoot oil, 111.
 Olive oil in, 115.
 Ozokerite oil in, 140.
 Palm oil, 103, 104, 106, 107, 109, 110, 120.
 Palm oil in, 121.
 Palm oil, yellow, 103.
 Paraffin in, 83.
 Paraffin oil, 132, 135.
 Petroleum jelly, 224.
 Piston-rod, 134.
 Pitch in, 119, 133.
 Rape oil, 107, 108, 109, 119.
 Rape oil in, 116, 117, 118, 140.
 Resin, 223.
 Rope, 138.
 Rosin, 80, 120, 132.
 Rosin oil in, 122, 123, 140.
 Schuckart's, 138.
 Soap, 108, 114, 221.
 Soap and petroleum jelly, 141.
 Soap and tallow, 115.
 Soap in, 87, 88.
 Soapstone in, 135.
 Soda, 102, 104, 106, 107, 108.
 Soda in, 116, 117.
 Soda crystals, 107, 108, 109.
 Solid, 137.
 Sperm oil, 107.
 Spring, 107.
 Spring and autumn, 102.
 Summer, 102, 107, 113.
 Talc in, 93, 94.
 Tallow, 102, 107, 110, 117, 141.
 Tallow and neatsfoot oil, 102.
 Tallow and train oil, 99, 100.
 Tar oil in, 135.
 Train oil, 107, 110, 113.
 Train oil in, 136.

Greases (*cont.*)—

Vaseline, olein, 120, 121.
 Waggon, 121, 122.
 Waterproof leather, 222.
 Wheel, 122.
 White patent, 136.
 Winter, 102, 107, 132.
 Wool, 146.
 Greasy rags, storing, 196.
 Greaves, 18, 34.
 Green vitriol in blacking, 208, 209, 214.
 Green vitriol in dégras making, 229.
 Ground-nut oil as lubricant, 32.
 Guaiacum, 137.
 Gum in blacking, 211, 213, 214.
 Guttapercha, 84.
 Guttapercha and caoutchouc grease, 117.
 Guttapercha polish, 211.
 Hanoverian blacking, 203.
 Harness grease, 222.
 Harness varnish, 216.
 Hazelnut oil, specific gravity of, 46.
 Hog fat, 44.
 Hog fat, specific gravity, etc., of, 35.
 Horse fat, 38, 103, 113.
 Horse fat, melting point and specific gravity of, 39.
 Hydrocarbon oils, 52, 53.
 Hydrocarbon oils as lubricants, 8.
 Hydrocarbons in shark oils, 17.
 Hydrocarbons of the benzene series, 61.
 Hypogoeic acid, formula, melting point, and origin of, 14.
 Illuminating oil, 57, 58, 59.
 Illuminating oils from Russian petroleum, 66.
 Indiarubber, 83-84.
 Indigo blacking, 212.
 Infusorial earth, 141.
 Iron blacking, 214.
 Isocholesterol, formula, melting point, and origin of, 16.
 Isocetic acid, formula, melting point, and origin of, 14.
 Isolinenic acid, formula, melting point, and origin of, 15.
 Ivory black, preparing, 204.
 Jecoleic acid, formula, melting point, and origin of, 14.
 Kerosene, 55, 59, 61.
 Kerosene, specific gravity, etc., of, 63, 66.
 Lamp black in blacking, 210-212.
 Lamp black in leather softeners, 222, 224, 225.
 Lamp black in leather varnish, 216, 217, 220.

- Tannolin axle grease, 141.
 Tannolin lubricant, 141.
 Tard in blacking, 212.
 Tard in leather softeners, 223, 224.
 Tard oil, specific gravity of, 44.
 Tauric acid, formula, melting point, and origin of, 14.
 Tawender oil in leather varnish, 216.
 Tlead acetate, 96, 111, 112, 117.
 Tlead oleate, 112, 113.
 Tlead oleate axle grease, 112.
 Tlead soap lubricants, 111, 112, 113.
 Leather, greased, gloss for, 223.
 Leather softeners—
 Alcohol in, 223.
 Ammonia soap in, 222.
 Asphaltum in, 222.
 Bone black in, 224.
 Caoutchouc in, 224.
 Carbolic acid in, 223.
 Colophony in, 222.
 Fish oil in, 221-224.
 Glycerin in, 221, 223.
 Harness, 222.
 Lamp black in, 222, 224, 225.
 Lard in, 223, 224.
 Linsced oil in, 222, 223.
 Nigrosine in, 223.
 Oleic acid in, 222.
 Olive oil in, 222.
 Petroleum jelly, 224, 225.
 Potash in, 222.
 Prussian blue in, 225.
 Rape oil in, 222, 224.
 Rosin in, 223, 224.
 Shellac in, 223.
 Soap in, 221-223.
 Spermaceti in, 223.
 Stearic acid in, 222.
 Sugar in, 222, 224.
 Sulphuric acid in, 224.
 Tallow in, 221, 224.
 Tannin in, 222, 223.
 Turpentine in, 223.
 Turpentine oil in, 222, 223, 224.
 Water in, 222, 223.
 Waterproof, 222.
 Wax in, 222, 223.
 Leather softening preparations, 201, 221, 222, 223, 224, 225.
 Leather stains, patent, 211.
 Leather varnishes, 215-220.
 Leather varnishes—
 Alcohol in, 216, 217.
 Asphaltum in, 215, 219.
 Benzol in, 219.
 Berlin blue in, 218.
 Black, 216.
 Black, for bolts, 217.
 Black harness, 217.
 Bone black in, 216, 219.
 Caoutchouc in, 216, 218, 219.
 Leather varnishes (cont.)
 Carbon disulphide in, 216.
 Gleni in, 217.
 Gallnuts in, 216.
 Harness, 216.
 Lamp black in, 216, 217, 220.
 Lavender oil in, 216.
 Linsced oil in, 215, 217, 218, 220.
 Petroleum in, 216, 218, 219.
 Prussian blue in, 217, 218.
 Resin in, 227-219.
 Sandarach in, 217.
 Shellac in, 216, 217.
 Syrup in, 216.
 Turpentine oil in, 215, 217, 218, 219.
 Umber in, 215.
 Vitriol in, 216.
 Water in, 216.
 Lighting oil and distillates, 57.
 Lignite blacking, 211.
 Lignite, montan wax from, 88.
 Lignite oils, distillation of, 76.
 Lignite tar, products from, 77.
 Lignoceric (carnaubic) acid, formula, melting point, and origin of, 14.
 Ligroin, specific gravity of, 66.
 Lime, 95.
 Lime in greases, 96, 131, 132, 135, 140.
 Lime soaps, 78, 80, 88, 135, 136, 137.
 Linolenic acid, formula, melting point, and origin of, 15.
 Linolic acid, formula, melting point, and origin of, 15.
 Linsced oil, 48.
 Linsced oil in blacking, 209.
 Linsced oil in leather softeners, 222, 223.
 Linsced oil in leather varnish, 215, 217, 218, 220.
 Linsced oil in lubricants, 115, 135.
 Liquid blacking, 213.
 Liquid fats, 9, 40, 106.
 Liquid lubricants, 125.
 Liquid oils, as lubricants, 40.
 Liquids, cooling, 173.
 Litharge, 96, 113, 117.
 Litharge in lubricants, 111, 112, 119.
 Litharge, refining oils with, 30.
 Logwood extract in blacking, 209, 213.
 Logwood in leather varnish, 216.
 Lowy's blacking, 213.
 Lubricant tester, cylinder, Bailey's
 Boul's patent, 191, 192.
 Lubricants, 1-200.
 Lubricants :—
 Almond oil, 45.
 Almond oil in, 149, 153.
 Alumina soap in, 89.
 Animal fats and oils in, 8.
 Application of, to machinery, 178-188.
 Aquadag in, 91, 92.

Lubricants (*cont.*)—

Asphaltum in, 83, 119.
 Beechnut oil, 32.
 Black lead in, 89.
 Bone fat in, 35, 36, 37, 38, 101.
 Bone oil, 36, 44, 125, 150.
 Caoutchouc in, 83, 116, 117, 153.
 Castor oil in, 47, 102.
 Chemical, 7.
 Clockmakers', 149-153.
 Coal oil in, 125.
 Coal tar oil in, 136.
 Cohesion oil as, 127-129.
 Coll's patent, 138.
 Colouring matter for, 135, 136, 141.
 Colza oil in, 125.
 Cutting, 173.
 Cylinder, 142-145.
 Dolphin oil in, 41.
 Drechsler's patent, 138.
 Earthnut oil in, 46.
 Fatty, 7-11, 40, 41, 42, 150.
 Glue in, 116, 117.
 Graphite in, 8, 9, 89, 91, 110, 138.
 Ground-nut oil, 32.
 Guttapercha in, 84, 117.
 Hazlenut oil in, 46.
 Hog fat in, 35.
 Horse fat in, 108, 113.
 Indiarubber in, 84.
 Lanolin, 141.
 Lard oil in, 44.
 Lead soap, 111, 112.
 Lime in, 95.
 Lime soap in, 88.
 Linseed oil in, 115, 116, 134, 141.
 Litharge in, 96, 99, 111, 112, 113, 117, 119, 134, 135.
 Magnesia soaps in, 89.
 Mineral, 7, 139.
 Mineral oil, 136, 139-141.
 Naphthalene, 119.
 Neatsfoot oil in, 42, 111, 125, 128.
 Oildag in, 91-93.
 Olein-vaseline, 120.
 Olive oil in, 8, 31, 32, 46, 47, 48, 115, 125, 137, 149, 150, 153.
 Ozokerite in, 125, 134.
 Palm oil, 39, 97, 101, 102, 103, 104, 105, 106, 107, 108, 103, 110, 120, 121, 128.
 Paraffin in, 83.
 Paraffin oil in, 132, 134, 135, 137.
 Paravasoline, 140, 141.
 Petroleum, 53, 54, 55, 56, 57, 58, 59, 60-66, 119, 125, 137, 153.
 Petroleum jelly, 141.
 Pitch, black in, 119.
 Pork fat in, 103, 111, 112, 120.
 Porpoise oil in, 41.
 Potash soaps in, 86, 87.
 Purifying waste, 196, 197.
 Quicklime in, 141.

Lubricants (*cont.*)—

Rape oil in, 45, 101, 102, 107, 108, 109, 111, 112, 116, 117, 118, 119, 125, 128, 129, 130, 132, 134, 137, 141, 149, 152, 153.
 Rosin in, 77, 78, 115, 120.
 Rosin oil, 78, 79, 80, 81, 82, 96, 120, 121, 122, 123, 125, 128, 129, 130, 131, 135, 136, 137.
 Sesamum oil, 32.
 Soap and mineral oil, 136.
 Soap in, 8, 9, 78, 85, 86, 87, 88, 89, 104, 108, 114, 134.
 Soap solutions in, 125.
 Soapstone in, 135.
 Soda crystals in, 102, 107, 108, 109.
 Soda in, 94, 95, 101, 102, 104, 106, 107, 116, 117.
 Soda lye in, 110.
 Soda soaps in, 84.
 Solar oil, 130.
 Solar oil in, 125.
 Solid, various, 80, 97-110, 119-124.
 Sperm oil in, 40, 107, 125.
 Steatite in, 8, 9.
 Sulphur in, 94, 101.
 Talc in, 93, 94, 134.
 Tallow in, 97, 98, 99, 101, 102, 107, 110, 115, 117, 120, 128, 129, 130, 135, 138, 141.
 Tallow oil in, 44.
 Tar oil in, 135.
 Thick oil, 130.
 Train oil in, 42, 99, 101, 102, 103, 107, 108, 110, 113, 116, 117, 125, 128, 130, 136, 138.
 Treated oils as, 8.
 Turpentine oil in, 116, 117.
 Use of, 199, 200.
 Vegetable fats and oils as, 8-10.
 Water in, 101, 102, 104, 105, 106, 107, 108, 109, 111, 112, 114, 115, 116, 117, 119, 132, 134, 153.
 Whale oil in, 41.
 Winter, 130.
 Lubricants, classification of, 6, 7.
 Lubricants, emulsion, 95, 97, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176.
 Lubricants, essential properties of, 5.
 Lubricants, fluidity and consumption of, 6, 7.
 Lubricants, greasers for thick or but-tery, 185, 186, 188.
 Lubricants, influence of temperature on, 11.
 Lubricants, liquid, 33, 125.
 Lubricants, liquid fats in, 40.
 Lubricants, liquid, from rosin oil, 80.
 Lubricants, mineral substances in, 9, 89.

- Lubricants, non-drying oil, 32.
 Lubricants, oils treated by alkali process for use as, 23.
 Lubricants, properties of, 5.
 Lubricants, special, 134.
 Lubricants, substances used in preparation of, 8-96.
 Lubricants, suitability of, for different machines, 5, 10, 11, 48, 49.
 Lubricating graphites, supplied by Graphite Products, Ltd., analyses of, 90.
 Lubricating greases, 71.
 Lubricating machinery, 178-188.
 Lubricating oil, mineral, 123.
 Lubricating oils, blown oils used in compounding, 51.
 Lubricating oils, compound (Wells and Southcombe), 146.
 Lubricating oils, cylinder, 142.
 Lubricating oils, fatty acids in, 146.
 Lubricating oils from Russian petroleum, 66, 67.
 Lubricating oils from shale, flash point of, 75.
 Lubricating oils, heavy mineral, table giving density, flash point, etc., of, 144.
 Lubricating oils in general, 125-126.
 Lubricating oils, mineral, 139-141.
 Lubricating oils, substitutes for, 177.
 Lubricating oils, testing, 189-192.
 Lubricating powder, Drechsler's graphito, 138.
 Lubrication, frictional resistance and, 2-5.
 Lubrication, "Gorm process" of (Wells and Southcombe), 146-148.
 Lubrication, marine, 146.
 Lubricator, "Kirkham" patent (Valvoline Oil Co.), 183, 184, 185.
 Lubricator, patent automatic (Trier Bros. Ltd.), 185, 186, 188.
 Lye soda, 109, 110, 141, 164.
 Lye in greases, 114, 115, 135.
 Lye used in neutralisation, 163.
 Lyons blacking, 208.
 Machine grease, caoutchouc, 116.
 Machine grease, rosin, 120.
 Machine greases, 97.
 Machine oil, specific gravity, etc., of, 66.
 Machine oils and greases, American, 137.
 Machine tools, soluble oils for, 165.
 Machinery, application of lubricants to, 178-188.
 Machinery, cleaning, 193, 194.
 Machinery, fine grease for, 102, 103, 133.
 Machinery, fine, oil for, 42, 43, 152.
 Machinery, selection of lubricants for, 199, 200.
 Machinery, wooden, grease for, 110.
 Machines, sewing, caoutchouc lubricant for, 153.
 Machines, sewing, cleaning, 194.
 Machines, sewing, mineral oil for, 153.
 Machines, sewing, oils for, 149, 150, 151, 152, 153.
 Magnesia, 140.
 Magnesia soaps, 89.
 Mineral oil and soap lubricants, 136.
 Melissic acid, formula, melting point, and origin of, 14.
 Motor, specific gravity, etc., of, 66.
 Mica, 94.
 Mineral lubricants, 7.
 Mineral lubricating oils, 139-141.
 Mineral lubricating oils, heavy, 144.
 Mineral oil emulsions, formation of, 176.
 Mineral oil for clocks, 152.
 Mineral oil for sewing machines, 153.
 Mineral oil, fractional distillation of, from various sources, 64, 65.
 Mineral oils, 49, 50, 52, 57, 89, 152, 153, 159, 166, 167, 168.
 Mineral oils for lubricating and other purposes, 172.
 Mineral oils in lubricants, 125.
 Mineral oils soluble in water, Boleg's patent for preparation of, 171-173.
 Mineral oils, soluble with olein basis, recipes of, 169, 170.
 Mineral oils, surface tension of, 146-147.
 Mineral substances in lubricants, 8, 9, 89.
 Motor cylinder oils, recipes for, 153, 154.
 Mucilage in oils, 125, 126.
 Mustard seed oil, 45.
 Myristic acid, formula, melting point, and origin of, 14.
 Naphtha, 55, 56, 61.
 Naphtha, specific gravity, etc., of, 63.
 Naphtha, U.S.A., exports, 54.
 Naphthalene grease, 119.
 Naphthenes, 60, 61.
 Naphthenic acid, 146.
 Nentsfoot oil, 36, 128.
 Nentsfoot oil as lubricants for fine machinery, 42.
 Nentsfoot oil, preparation, etc., 42-44.
 Nentsfoot oil, specific gravity of, 42.
 Neutral oils, 155.
 Nigrosine in leather softeners, 2-3.
 Nitric acid in blacking, 214.
 Nitro-hydrochloric acid method of refining bone fat, 36, 37.
 Non-drying oils, 10, 32.
 Nut oil, 49.

- Oil and grease, removing thickened, 193, 194.
 Oil, Broxburn crude shale, 75.
 Oil can, aerostatic, 180, 181.
 Oil can, flexible, 179, 180.
 Oil, crude shale, products from, 75.
 Oil, crude shale (Young's), 76.
 Oil cups, 181, 182, 183, 186.
 Oil emulsions, mineral, formation of, 176.
 Oil fields, petroleum, 56.
 Oil filter, Turner's patent (Valvoline Oil Co.), 197, 198.
 Oil for lubricating gas engine, 152.
 Oil of turpentine in blacking, 208, 210.
 Oil of turpentine in lubricants, 116, 117.
 Oil, original, and blown oil, comparison of analytical figures for the (Lewkowitsch), 50.
 Oil rags, cleaning, 195, 196.
 Oil rags, storing, 196.
 Oil refineries in Baku, 56.
 Oil refineries in Japan, 59.
 Oil refineries in U.S.A., 55.
 Oil seeds, hydraulic press for, 19.
 Oil tester, Bailey's Thurston's patent, 189, 190.
 Oil testing machine, 190.
 Oil wells, petroleum, 53, 54, 55, 56, 57.
 Oiler, patent snapdrop, "Kirkham," 183.
 Oils—
 Almond, 8, 45, 149, 153.
 Anthracene, 71.
 Beechnut, 32.
 Bone, 8, 36, 44, 125, 150, 151.
 Carbolic, 71.
 Castor, 8, 47, 49, 50, 52, 158, 159, 161, 162, 165.
 Clockmakers', 149-153.
 Coal, 125.
 Coal-tar, 8, 71, 136.
 Coconut, 33, 140.
 Cohesion, 127, 128, 129.
 Cottouseed, 137.
 Creosote, 71.
 Cutting, 52, 173.
 Cylinder, 142, 143, 144, 145.
 Dolphin, 8, 41.
 Drying, 10, 49.
 Eagle, 140.
 Earlnut, 8, 46.
 Fish, 135, 207, 210, 211, 212, 214, 227, 28.
 Globe, 140.
 Ground-nut, 32.
 Guaiacum, 137.
 Hazelnut, 8, 46.
 Hydrocarbon, 8, 52, 53.
 Illuminating, 57, 58, 59.
 Lard, 8, 44.
 Oils (*cont.*)—
 Lignite, 8, 76.
 Lignite tar, 76, 77.
 Linseed, 48, 115, 134, 135, 140, 141, 222, 223.
 Liquid, 40.
 Mineral, 49, 50, 52, 57, 125, 139, 140, 141, 152, 153, 155, 166, 167, 168.
 Mucilage in, 125-126.
 Mustard seed, 8, 45.
 Neatsfoot, 8, 36, 42, 111, 125, 128.
 Neutral, 59.
 Non-drying, 10, 32.
 Non-emulsifiable, 146.
 Nut, 49.
 Olive, 8, 31, 32, 46, 47, 48, 115, 125, 137, 149, 150, 153, 156, 165, 211, 213, 222.
 Ozokerite, 140.
 Palm, 7, 8, 13, 33, 39, 40, 101, 109, 110, 120, 121, 128.
 Paraffin, 63, 132, 134, 135, 137.
 Petroleum, 8, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 123, 125, 153, 167.
 Phoenix, 140.
 Porpoise, 8, 41.
 Rape, 8, 45, 48, 101, 103, 107, 108, 109, 116, 117, 118, 119, 125, 128, 129, 130, 132, 137, 140, 141, 146, 149, 152, 153.
 Refining, 23-32, 63, 125, 126, 149, 150, 151, 152.
 Rosin, 7, 8, 78, 79, 80, 81, 82, 125, 128, 129, 130, 131, 135, 136, 137, 140, 167.
 Screwing, 52.
 Sesamum, 32.
 Shale, 8, 53, 71, 72, 73, 74, 75, 76.
 Solar, 77, 125, 130.
 Soluble, 156-173.
 Sperm, 8, 40, 125.
 Sulphonated, 8, 52, 156, 161, 164.
 Summer, 129.
 Tallow, 8, 33, 44, 112.
 Tar, 7, 51, 135.
 Tar-grease, 122.
 Train, 40, 42, 107, 108, 110, 113, 116, 117, 125, 128, 130, 136, 138.
 Turbine, 137.
 Turkey red, 156, 159, 162, 163.
 Turpentine, 116, 117, 121, 130, 134, 135, 215, 217, 218, 219, 222, 223, 224.
 Vegetable, 48.
 Volatile, 49, 61, 77, 130.
 Vulcan, 140.
 Whale, 8, 41, 51, 146.
 Winter, 129.
 Oils, American machine, 137.
 Oils, animal, surface tension of, 146, 147.

- Oils and fats, properties of, 33.
 Oils and fats, purification of, 20, 21, 22.
 Oils, clarifying, filter press for, 22.
 Oils, clarifying, settling tank for, 21.
 Oils, cottonseed, blown, table showing results, 51.
 Oils, crude shale, distillation of, 75.
 Oils, crude shale, yield of, from various products (Gesner), 73.
 Oils, cylinder lubricating, 63.
 Oils, fatty, surface tension of, 147.
 Oils, fish blown, table showing results, 51.
 Oils, hydrocarbon, in lubricants, 8.
 Oils, illuminating, U.S.A. exports of, 54.
 Oils, lubricating, blown oils used in compounding, 51.
 Oils, lubricating, substitutes for, 177.
 Oils, mineral, for lubricating and other purposes, 172.
 Oils, mineral, soluble in water, Bolog's patent for preparation of, 171-173.
 Oils, mineral, surface tension of, 146, 147.
 Oils, motor cylinder, recipes for, 153, 154.
 Oils, neutral, versus fatty acids, in reducing friction, 148.
 Oils, non-drying, as lubricants, 32.
 Oils, petroleum, exports of Galicia, 57.
 Oils, petroleum, exports of Roumanian, 57.
 Oils, petroleum, fractionation of, after second distillation, 63.
 Oils, petroleum, production of, in Galicia, 57.
 Oils, petroleum, production of, in Japan, 57.
 Oils, petroleum, production of, in Roumania, 57.
 Oils, polymerisation of, 49.
 Oils, refining, caustic potash in, 28.
 Oils, refining, sulphuric acid process of, 23, 24, 25, 26, 29, 31.
 Oils, refining, tannin process of, 26, 27.
 Oils, refining, with caustic soda, 27, 28.
 Oils, refining, with litharge, 30.
 Oils, refining, zinc oxide method of, 29, 30.
 Oils, rosin, for lubricating and other purposes, 172-173.
 Oils, rosin, soluble in water, Bolog's patent for preparation of, 171-173.
 Oils, semi-drying, blown, table showing results, 51.
 Oils, shale, yield of paraffin from, 82.
 Oils, shark, hydrocarbons in, 17.
 Oils, solidified, 123, 124.
 Oils, solidified, analysis of, by Heller, 124.
 Oils, soluble, and soluble compounds, 174.
 Oils, soluble, containing rosin, recipes of, 170, 171.
 Oils, soluble, for machine tools, 165.
 Oils, soluble, method of preparing, 52.
 Oil, soluble mineral, with olein bases, recipes of, 169, 170.
 Oils, soluble, particulars relating to (reprinted from "Oil and Colour Trades Journal,"), 156-165.
 Oils, soluble rosin, recipes of, 170.
 Oils, soluble, two formulae for, 168.
 Oils, soluble, with sulpholein bases, recipes of, 170.
 Oils, solvent process of extracting, from seeds, 18, 19, 20.
 Oils, sulphated, analyses of, 174-176.
 Oils, tar, soluble in water, Bolog's patent for preparation of, 171-173.
 Oils, tar, soluble in water, uses of, 173.
 Oils, treated, as lubricants, 8, 49.
 Oils treated by alkali process for use as lubricants, 23.
 Oils, various, soluble in water and easily emulsifiable, 174-173.
 Oils, vegetable, extraction of, 18.
 Oils, vegetable, surface tension of, 146-147.
 Olefines, 60, 61.
 Oleic acid, 13, 52, 112, 113, 137, 166, 167, 168.
 Oleic acid, formula, melting point, and origin of, 14.
 Oleic acid in leather softeners, 222.
 Olein, 13, 137.
 Olein dégras, 223, 229.
 Olein in neatfoot oil, 42.
 Oleine, 112, 165.
 Olive oil in blacking, 214, 215.
 Olive oil in leather softeners, 222.
 Olive oil in lubricants, 8, 31, 32, 46, 47, 48, 115, 125, 137, 149, 150, 153.
 Olive oil, specific gravity of, 47.
 Ozokerite, 56, 126, 134, 144.
 Ozokerite oil, 140.
 Ozokerite paraffin, specific gravity of, 83.
 Palmitic acid, formula, melting point, and origin of, 14.
 Palmitin in neatfoot oil, 42.
 Palm oil, 7, 8, 13, 104, 107, 109, 128.
 Palm oil and soda greases, 104, 106.
 Palm oil bleaching, 39.
 Palm oil extraction, 39.
 Palm oil greases, 103, 109.

- Palm oil in lubricants, 97, 103, 110, 120, 121.
 Palm oil in manufacture of lubricants, 39.
 Palm oil, melting point and specific gravity of, 89, 40.
 Palm oil, preparation of, 105.
 Palm oil, yellow, 103.
 Paraffin, 8, 57.
 Paraffin and petroleum jelly, 133.
 Paraffin in lubricating greases, 83.
 Paraffin oil in lubricants, 132, 135, 137.
 Paraffin oil, specific gravity, etc., of, 63.
 Paraffin, ozokerite, specific gravity of, 83.
 Paraffin, specific gravity and melting point of, 82, 83.
 Paraffin, U.S.A. exports, 54.
 Paraffin wax, 56, 82.
 Paraffins detected in Pennsylvanian petroleum, specific gravity, boiling point, etc., of, 60.
 Paraffins, solid, 83.
 Paravaseline as a lubricant, 140.
 Paris blue in blacking, 214.
 Patent caoutchouc grease, 224.
 Patent graphite lubricating powder, Drechsler's, 138.
 Patent leather stains, 211.
 Petrol, 61.
 Petroleum, 54, 137.
 Petroleum benzine, 18, 20.
 Petroleum, crude, Galician exports of, 57.
 Petroleum, crude, production of, in Galicia, 57.
 Petroleum, crude, production of, in Roumania, 57.
 Petroleum, crude, Roumanian exports of, 57.
 Petroleum, crude, Russian, production of, in 1913 and 1914, 56.
 Petroleum, crude, specific gravity, etc., of, 60.
 Petroleum, crude, still for, 62.
 Petroleum, crude, yield of paraffin from, 82.
 Petroleum, distillation of, 61, 62, 63.
 Petroleum ether for cleaning rags, etc., 195.
 Petroleum ether, specific gravity, etc., of, 66.
 Petroleum for cleaning machinery, 193, 194.
 Petroleum in leather varnish, 216, 218, 219.
 Petroleum in lubricants, 153.
 Petroleum jelly, 7, 124.
 Petroleum jelly and paraffin grease, 133.
 Petroleum jelly as a leather preservative, 224.
 Petroleum jelly as a lubricant, 141.
 Petroleum jelly, paraffin in, 83.
 Petroleum oil fields, 56.
 Petroleum oil refineries, 55.
 Petroleum oils, fractionation of, after second distillation, 63.
 Petroleum oils in lubricants, 8, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 119, 167.
 Petroleum oils, separation of, by fractionation, after second distillation, 63.
 Petroleum, Pennsylvanian, specific gravity, boiling point, etc., of paraffins detected in, 60.
 Petroleum products, imports of, into U.K. in 1914, 58.
 Petroleum products refined after first distillation, 63.
 Petroleum, Russian, products from, 63, 66, 67.
 Petroleum spirit, 57.
 Petroleum well-sinking in U.S.A., 53, 54.
 Petroleum, world's production of, for various years, 59.
 Phytostoleic acid, formula, melting point, and origin of, 14.
 Phytosterol, formula, melting point, and origin of, 16.
 Piston-rod grease, 134.
 Pitch, black, 119.
 Pitch, brewer's, in grease, 138.
 Polishes—
 Black, in sticks, 203.
 Guttapercha, 211.
 Shoe, 201-214.
 Spermaceti, 210.
 Wax, 210.
 Polymerisation of oils, 49.
 Polymerised oils, 8, 49.
 Pork fat in lubricants, 111, 112, 120.
 Porpoise oil in lubricants, 8, 41.
 Potash, caustic, 13.
 Potash, 115.
 Potash in blacking, 210.
 Potash in leather softeners, 222.
 Potash soaps, 9.
 Potash soaps in lubricants, 86, 87.
 Potash solution in dégras making, 226, 227, 228, 229.
 Potassium chromate in blacking, 209.
 Potassium ferrocyanide in blacking, 214.
 Potatoes in blacking, 212.
 Prussian blue in blacking, 210, 212.
 Prussian blue in leather softeners, 225.
 Prussian blue in leather varnish, 217, 218.
 Pyronaphtha, specific gravity, etc., of, 66.

- Quicklime in lubricants, 141.
- Railway grease, 141. *See also* Axle grease.
- Rancidity, 10, 13, 48, 49, 126.
- Rape oil, 8, 48, 101, 107, 108, 109, 111, 112, 128, 129, 132, 137, 146.
- Rape oil in leather softeners, 222, 224.
- Rape oil in lubricants, 45, 101, 102, 107, 108, 109, 111, 112, 116, 117, 118, 119, 125, 128, 129, 130, 132, 134, 137, 141, 149, 152, 153.
- Rape oil refining, 27, 30, 31, 152.
- Rape oil, specific gravity, etc., of, 45.
- Rapic acid, formula, melting point, and origin of, 14.
- Refineries, petroleum oil, 55.
- Refining bone fat with nitro-hydrochloric acid, 36.
- Refining bone oil, 150, 151.
- Refining oil with bleaching powder, 152.
- Refining oil with lye, 150.
- Refining oil with sulphuric acid, 150.
- Refining oils, 23-32, 63, 125, 126, 149, 150, 151, 152.
- Refining rape oil, 27, 30, 31, 152.
- Refining train oil, 99.
- Rosin grease for leather, 223.
- Rosin in leather softeners, 223, 224.
- Rosin in leather varnish, 217-219.
- Retorts used in shale oil industry, 74.
- Rhigolene, boiling point, etc., of, 63.
- Ricinoleic acid, 13.
- Ricinoleic acid, formula, melting point, and origin of, 15.
- Rock oil, 53.
- Rope grease for wire ropeways, 138.
- Rosin, 8.
- Rosin, asphaltic residue in, 79.
- Rosin, dry distillation of, 81-82.
- Rosin greases (Joan), 132.
- Rosin machine grease, 120.
- Rosin oil, 7, 8, 128, 129, 167.
- Rosin oil and fat lubricants, 130.
- Rosin oil and train oil lubricant, 130.
- Rosin oil, blue, 137.
- Rosin oil, distillation of, 79.
- Rosin oil in lubricating grease, 96.
- Rosin oil, preparation of, 81.
- Rosin oil, refining of, 80.
- Rosin oil, yellow, 137.
- Rosin oils for lubricating and other purposes, 172-173.
- Rosin oils soluble in water, Bolog's patent for preparation of, 171-173.
- Rosin oils, soluble, recipes of, 170.
- Rosin oils, specific gravity of (Lewkowsch), 80.
- Rosin, products of, by distillation, 79.
- Rosin, saponification value of, 78.
- Rosin soaps, 78, 141, 169.
- Rosin, still for distilling, 81, 82.
- Sandarach in leather varnish, 217.
- Saponification, cleaning rags by, 196.
- Screwing oils, 52.
- Sesamum oil as lubricant, 32.
- Sewing machines. *See* Machines, sewing.
- Shale, lubricating oils from, flash point of, 75.
- Shale oils, 8, 53, 71.
- Shale oil, crude, Broxburn, 75.
- Shale oil, crude, products from, 75.
- Shale oil, crude (Young's), 76.
- Shale oil, distillation of, 72, 74, 75.
- Shale oil industry, 72-76.
- Shale oil works, products manufactured in, 73.
- Shale oil, yield of paraffin from, 82.
- Shale, Scotch, analysis of, 74.
- Shale yields on distillation, Broxburn, 74.
- Shamoying for dégras, 226, 227.
- Shellac in blacking, 214.
- Shellac in leather softeners, 223.
- Shellac in leather varnish, 216, 217.
- Shoe polishes, 201-214.
- Soap and mineral oil lubricants, 136.
- Soap and petroleum jelly grease, 141.
- Soap grease for boot uppers, 221.
- Soap greases, 114, 115.
- Soap in blacking, 208.
- Soap in leather softeners, 221-223.
- Soap in solid greases, 88.
- Soap, lead, 113.
- Soap (lead) lubricants, 111.
- Soap, lime, 135.
- Soap, rosin, 141, 169.
- Soaps, alkali, 13.
- Soaps, alumina, 9, 89.
- Soaps, analyses of various, 87.
- Soaps, hard, analyses of, 86.
- Soaps in lubricants, 8, 9, 78, 85, 86, 87, 88, 89, 104, 108, 114, 134.
- Soaps, lime, 9, 78, 80, 88.
- Soaps, magnesia, 9, 89.
- Soaps, potash, 9, 86.
- Soaps, soda, 9, 84.
- Soapstone. *See also* Talc.
- Soapstone, 91, 135.
- Soda, 9, 167.
- Soda ash, 95.
- Soda, carbonate of, 91.
- Soda, caustic, 12.
- Soda, caustic, refining oils with, 27, 28.
- Soda crystals, 95, 101, 108, 109.
- Soda crystals converted into caustic soda, 105.
- Soda crystals in lubricants, 102.
- Soda greases, 102.
- Soda greases, preparation of, 105.

- Soda in blacking, 207, 210.
 Soda in greases, 116, 117.
 Soda lye, 109, 110, 141, 164.
 Soda lye, caustic, 168.
 Soda lye in greases, 135.
 Soda lye in making dégras, 228.
 Soda soaps in lubricants, 9, 84.
 Soda, sulphate of, 160, 161, 162, 164.
 Sodium oleate, 13.
 Sodium salts of the acids as emulsifying agents, 155.
 Solar oil, light, specific gravity, etc., of, 66.
 Solar oil lubricant, 130.
 Solid lubricants, various, 97-110, 119-124.
 Solid paraffins, 83.
 Solidified oils, analyses of, by Heller, 124.
 Soluble oil, method of preparing, 52.
 Soluble oils, 156-173.
 Soluble oils and soluble compounds, 174.
 Soluble oils, commercial, 169.
 Soluble oils containing rosin, recipes of, 170, 171.
 Soluble oils for machine tools, 165.
 Soluble oils, manufacture of, 156, 165.
 Soluble oils, two formulae for, 168.
 Soluble oils with sulpholeate basis, recipes of, 170.
 Soluble mineral oils with olein basis, recipes of, 169, 170.
 Soluble rosin oils, recipes of, 170.
 Solvent extraction plant (Cl. Scott & Sons), 20, 21.
 Spermaceti in blacking, 210.
 Spermaceti in leather softeners, 223.
 Spermaceti polish, 210.
 Sperm oil, 8, 16, 40, 107.
 Sperm oil, specific gravity of, 40.
 Spindle oil, specific gravity, etc., of, 66.
 Spirit of wine in blacking, 214.
 Spring grease, 107.
 Starch in blacking, 208.
 Stearic acid, formula, melting point, and origin of, 14.
 Stearic acid in leather softeners, 222.
 Stearin in neatsfoot oil, 42.
 Steatite. *See* Talc.
 Sterols in fats and oils, 16.
 Still for crude petroleum, 62.
 Sugar in blacking, 210, 213, 214.
 Sugar in leather softeners, 222, 224.
 Sugar of lead, 96, 111, 112, 117.
 Sugar of lead in lubricants, 111, 112.
 Sulphate of soda, 160, 161, 162, 164.
 Sulphonated castor oil as emulsifying agent, 156.
 Sulphonated oils, 8, 52, 156, 161, 164.
 Sulphonated oils, analyses of, 174-176.
 Sulphur axle grease, 101.
 Sulphuric acid, 23, 24, 25, 26, 52, 156, 157, 158, 159, 160, 161, 162, 164, 165.
 Sulphuric acid in blacking, 207, 209, 210, 212, 213, 214.
 Sulphuric acid in leather softeners, 224.
 Sulphuric acid in oil purification, 22.
 Sulphuric acid process of refining oils, 22, 23, 24, 25, 26, 29, 31.
 Sulphur, specific gravity, etc., of, 94.
 Summer greases, 107, 113.
 Syrup in blacking, 207-214.
 Syrup in leather varnish, 216.
 Talc as a lubricant, 141.
 Talc, specific gravity of, 93, 94.
 Tallow, 9, 11, 97, 98, 99, 101, 102, 107, 109, 110, 115, 117, 120, 128, 129, 130, 135, 138, 141.
 Tallow and castor oil grease, 102.
 Tallow and neatsfoot oil grease, 102.
 Tallow and train oil grease, 99, 102.
 Tallow, boiler for melting, 17.
 Tallow, crude, purification of, 34, 35, 36.
 Tallow grease, 102.
 Tallow in blacking, 208.
 Tallow in leather softeners, 221, 224.
 Tallow in lubricants, 84, 97, 98, 99, 101, 102, 107, 110, 115, 117, 120, 128, 129, 130, 135, 138, 141.
 Tallow lubricants, 97, 98, 99, 102.
 Tallow, specific gravity and melting point of, 33, 34.
 Tallow, purification of, 34, 35.
 Tallow oil, 8, 33, 44, 112.
 Tallow, oil and soap grease, 115.
 Tallow, rape oil and soda greases, 102.
 Tan in blacking, 209, 214.
 Tanner's grease, 226, 228, 229.
 Tannin extract in dégras making, 229.
 Tannin in blacking, 214.
 Tannin in leather softeners, 222, 223.
 Tannin process of refining oils, 26, 27.
 Tar, 138.
 Tar, coal, 137.
 Tar, coal, chief constituents of (Lunge), 68, 69, 70.
 Tar, coal, composition of, 67.
 Tar, coal, distillation of, 70, 71.
 Tar, coal, specific gravity, etc., of, 67.
 Tar, coal, still, 70, 71.
 Tar, coke oven, 71.
 Tar from Russian petroleum, 67.
 Tar, lignite, products from, 77.
 Tar oils soluble in water, Bolog's patent for preparation of, 171-173.
 Tar oils, soluble in water, uses of, 173.
 Tar oils, thickening agent for, 51,

- Temperature, influence of, on lubricants, 11, 40.
 Testefas, specific gravity, etc., of, 66.
 Tiglic acid, formula, melting point, and origin of, 14.
 Tool lubricants, 162.
 Tools, machine, soluble oils for, 165.
 Train oil, 40, 42, 103, 110, 113, 128, 136, 138.
 Train oil and tallow grease, 102.
 Train oil as a lubricant, 42.
 Train oil greases, 99, 100, 101.
 Train oil in lubricants, 42, 99, 101, 102, 103, 107, 108, 110, 113, 116, 117, 125, 128, 130, 136, 138.
 Tripalmitin, 12, 13.
 Turbine oils, 137.
 Turkey red oil, 156, 159, 162, 163.
 Turpentine, 77.
 Turpentine in leather softeners, 223.
 Turpentine oil. *See also* Oils, turpentine.
 Turpentine oil in leather softeners, 222-224.
 Umber in leather varnish, 215.
 Use of lubricants, 199, 200.
 Valeric acid, formula, melting point, and origin of, 14.
 Varnish—
 Asphaltum, 219.
 Black, for belts, 217.
 Black harness, 217.
 Black leather, 216.
 Caoutchouc, 218, 219.
 Caoutchouc, for rubber shoes, 219.
 Caoutchouc repairing, 219.
 Elastic caoutchouc, 218.
 Elastic leather, 217.
 Flexible blue, 217.
 Glossy black leather, 215.
 Harness, 216.
 Liquid asphaltum, glossy, 219.
 Varnishes, black, asphaltum in, 83.
 Varnishes for leather, 215-220.
 Varnishes, glossy, 215, 219.
 Vegetable and animal oils, surface tension of, 146-147.
 Vegetable oils, 8, 48, 49.
 Vegetable oils, extraction of, 18.
 Vienna oil blacking, 207.
 Vinegar in blacking, 213.
 Viscosin, 56.
 Viscosine, specific gravity, etc., of, 67.
 Vitriol, green, in blacking, 203, 209, 214.
 Vitriol, green, in dégras making, 229.
 Vitriol in leather varnish, 216.
 Volatile fat solvents, 18.
 Volatile fatty acids, 50.
 Volatile oils, 49, 61, 77, 130.
 Vulcan oil, 140.
 Waggon greases, 121, 122.
 Waste fat, dégras from, 229.
 Water in blacking, 207, 208, 209, 210, 211, 213, 214.
 Water in leather softeners, 222, 223.
 Water in leather varnish, 216.
 Water in lubricants, 101, 102, 104, 105, 106, 107, 108, 109, 111, 112, 119, 132, 153.
 Waterproof caoutchouc blacking, 209.
 Waterproof grease, glossy, 222.
 Waterproof leather grease, 222.
 Wax in blacking, 208, 210.
 Wax in leather softeners, 222, 223.
 Wax, paraffin, 82.
 Wax polish, 210.
 Wax shoe polish, 210.
 Whale oils, 8, 51, 146.
 Whale oil, specific gravity of, 41.
 Wheel greases, 122.
 White patent grease, 136.
 Winter grease, 107.
 Wire ropeways, grease for, 138.
 Wooden machinery, grease for, 110.
 Wool fat, purifying, 141.
 Wool grease, 146.
 Zinc oxide method of refining oils, 29, 30.
 Zinc oxide white, 29.

